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Volume II

THE GEOLOGY AND PALEONTOLOGY OF THE MARINE PLIOCENE OF SAN DIEGO, CALIFORNIA

PART 2a, PALEONTOLOGY

(COELENTERATA, BRYOZOA, BRACHIOPODA, ECHINODERMATA)

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FOREWORD

Part 1 of this memoir, issued August 30, 1944, contains a description of the general geology of the San Diego region. The present part begins the systematic account of the Pliocene fossils of this region, treating four phyla. Further experience in the field and laboratory has added to our knowledge much that can be used to advantage in the portions of this work dealing with paleontologic collections, their relationships, and their significance. We therefore hope that an improvement in presentation will compensate for the delay in publication.

Since the appearance of Part 1, geological field work in the San Diego region, chiefly accomplished or instigated by Professor E. Dean Milow, San Diego State College, has brought to light some further details of structure. These details will be discussed more fully in a concluding portion of the memoir, but three of them should be mentioned now. (1) The Soledad anticline is faulted and structurally more complex than originally assumed. (2) The Mission Valley fault, indicated in our text figure (page 50 in Part 1) as a hypothetical one, seems to have received some confirmation in the discovery of a down-faulted wedge of Pliocene strata just north of the mouth of the valley. (3) Some windows of Eocene sediments, identified from studies of microfossils, occur in the bottoms of some of the canyons in, north of, and northeast of Balboa Park where our map indicated Pliocene. These small Eocene windows are difficult to detect because of the lithologic similarity and the slight difference in dip between the Eocene and Pliocene sediments.

A recent treatise on the archaeology of the San Diego region by Professor George F. Carter[1], containing a discussion of the many terraces, may be of interest to the student of physiography or of the Pleistocene and Recent history of that area. Professor Carter believed that the terraces record eustatic changes of sea level rather than intermittent diastrophic uplifts.

ACKNOWLEDGMENTS

Many individuals have aided us during the preparation of this paper. Acknowledgment is made to some of them in the text. Special acknowledgment is due Dr. G. Dallas Hanna, Curator, Department of Geology, California Academy of Sciences, and Mr. Allyn G. Smith, Research Malacologist in the same institution, who have aided and advised the authors on many occasions. Likewise, Miss Veronica Sexton and Mr. Ignatius M'Guire of the library staff of the California Academy of Sciences have aided the authors on many occasions with reference work and in securing needed literature. Mr. Alan E. Leviton, Department of Herpetology, contributed valuable criticism concerning the section dealing with classification and nomenclature. Dr. J. Wyatt Durham, Associate Professor of Paleontology, University of California at Berkeley, identified specimens of corals for us, and Dr. John W. Wells, Cornell University, and Dr. Donald F. Squires, American Museum of Natural History, furnished information concerning certain species of this class. Some of the Bryozoa mentioned in the present paper were identified by Dr. R. S. Bassler of the United States National Museum. Later, the same specimens and additional ones were identified by Dr. John D. Soule, Allan Hancock Foundation, University of Southern California. Mr. Fred C. Ziesenhenne of the same institution aided in the identification of some of the fossil echinoderms and furnished important information after comparing them with Recent specimens.

We especially wish to acknowledge the courtesy of Mr. George P. Kanakoff, Curator of the Department of Invertebrate Paleontology, Los Angeles County Museum, who lent us a fine series of exceptionally well-prepared corals, bryozoa, brachiopods, and echinoids, which were collected from the San Diego formation. Dr. Hildegarde Howard of the same institution approved and facilitated the loan.

Fossils from the San Diego formation in the collections of the San Diego Society of Natural History were lent us by Kate Stephens, late Curator of Marine Invertebrates; and Mr. Emery P. Chace, present Curator, lent additional specimens and aided in other ways. Dr. William K. Emerson, formerly

(1) Carter, G. F., "Pleistocene Man at San Diego," (Johns Hopkins Press, Baltimore), pp. 1-400, 6 tables, 96 figs., 1957.

Museum Paleontologist in the Department of Paleontology at the University of California, Berkeley, California, (now with the American Museum of Natural History in New York), made available collections in that institution, checked certain references for us, and aided us in various ways. Mr. Edwin C. Allison and Mr. Joseph H. Peck, Jr., Museum Paleontologists in the same department, likewise aided us whenever called upon for information. Dr. Hubert G. Schenck and Dr. A. M. Keen have given us free access to the collections in the Department of Geology at Stanford University, and Dr. Willis P. Popenoe and Mr. Takeo Susuki, Department of Geology at the University of California at Los Angeles, made available the collections of that institution. Professor E. Dean Milow, San Diego State College, furnished specimens of fossils from the San Diego formation as well as information concerning certain localities in that area. Some specimens in the United States National Museum which were collected by Henry Hemphill from the San Diego well, were lent us by Dr. Paul Bartsch, Curator of the Division of Mollusks in the National Museum. Later, Dr. G. A. Cooper in the same institution lent specimens of fossil brachiopods from Cedros Island, Lower California, Mexico, and from southern California.

The following individuals aided us in furnishing information concerning type specimens in their respective institutions: Dr. Ruth Turner and Dr. Elizabeth Deichmann, Museum of Comparative Zoology, Harvard University; Mr. Percy A. Morris, Peabody Museum of Natural History, Yale University; Dr. Leslie R. Cox and Dr. Helen M. Muir-Wood, British Museum (Natural History), London; Dr. André Franc, Museum National d'Histoire Naturelle in Paris. Dr. M. H. deLaubenfels, Oregon State College, examined several specimens to ascertain whether these were bored by sponges. Mr. Robert Lando, formerly a resident of San Diego, made available a manuscript containing the results of his study of Recent and fossil mollusks at San Diego. The illustrations used in the plates are from photographs made by Mr. Charles E. Crompton, Photographer, California Academy of Sciences.

CLASSIFICATION AND NOMENCLATURE

The ideal natural classification of all organisms would group together closely related forms and separate those that are distantly or not related. Phylogeny, therefore, should be the fundamental basis of a natural system of classification of all organisms. All modern systematists no doubt agree on this point. They do not agree, however, concerning the significance and interpretation of the various taxonomic categories. Disagreements arise because the use of different characters leads to differences in classification. Furthermore, the use of a few large inclusive groups by one systematist conflicts with the use of more numerous finely divided, narrowly restricted groups by another systematist. Added to these disagreements, the application of the International Rules of Zoological Nomenclature frequently leads to complex legal questions which are variously interpreted by different authors or disregarded entirely by others: even decisions of the Commission may be reversed by the Commission at a subsequent meeting. This unfortunate state of affairs has led to much confusion, much argumentative literature, and an altogether lamentable expenditure of time and effort without actually adding much that is fundamental to our knowledge of nature. Consequently, in view of the present-day unsatisfactory condition of paleontologic systematics, it seems desirable at the beginning of this portion of the memoir that its authors express their viewpoints concerning nomenclature.

The authors subscribe to the general application of the International Rules of Zoological Nomenclature and most particularly to the rule of priority, which they are convinced is the cornerstone of these rules. They have deviated from this rule only rarely and only where a long-established and well-known name cannot be employed through strict adherence to this rule. Some of these well-known names later may be validated either by a suspension of the rules (as in the case of the recent validation of *Modiolus* Lamarck, 1799, replacing the earlier *Volsella* Scopoli, 1777) or through application of the "Principle of Conservation" (Internat. Rules Zool. Nomencl., 1953, pp. 119-122). Suspension of the rules, however, does not always stabilize nomenclature. Nicol[2] pointed out that in one case such action resulted in the

[2] Nicol, D., Jour. Washington Acad. Sci., Vol. 40, No. 3, p. 82, March 15, 1950. See also McKerrow, W. S., "Fossil Species and the Rules of Nomenclature" [in] "The Species Concept in Palaeontology" (P. C. Sylvester-Bradley, editor), Systematics Association, Publ. No. 2, p. 122, 1956.

necessity for a change of the name of a well known genus (the replacement of *Corbis* Cuvier by *Fimbria* Megerle von Mühlfeld).

In the differentiation of genera and species, dependence has been placed upon a totality of characters, where possible, rather than upon one character. Characters of the shells and of other hard parts that are preserved as fossils are given more emphasis than those of soft parts that can be studied only in living material — and sometimes are given exclusive mention. Although the anatomy of soft parts is very important in systematic zoology, traces of these are rarely preserved in rocks; and the paleontologist must rely on what is usually preserved.

In the treatment of species, a more definite and objective concept than that of the genus, it is hoped that an intermediate logical course has been followed, characterized neither by excessive "splitting" nor by excessive "lumping." The authors do not believe in naming new forms unless these are distinguished by characters that appear relatively constant, but they are fully aware of the need of fine stratigraphic delimitation of species based upon objective characters, no matter how small the differences may be.

Recognition of these species, whose stratigraphic ranges are often narrowly limited, is very useful in determining chronological sequence of strata. Also important in deciphering the earth's history are some closely similar forms separated by great stratigraphic range, which may represent a long time interval.

The paleobiologist emphasizes continuity within phylogenetic lineages of biologic forms by which their evolution may be understood. The paleontologist, on the other hand, while recognizing the importance of the phylogenetic sequence, looks especially for the breaks in the sequence which permit the recognition of distinct morphological units whose geologic ranges are frequently short. On the basis of such units, paleontologists are able to assign an age to and to correlate strata deposited approximately contemporaneously. The viewpoint of the paleontologist has been ably presented by Weller[3].

One of the most important aims of all paleontological work is the interpretation of the fossil record. Precise correlation of strata, interpretation of the conditions under which these strata were deposited, and elaboration of the geological history of local basins and provinces, should result in a knowledge of the history of continents and oceanic basins.

For the ultimate aim to be more quickly realized, it is important to compare species and genera that are now far separated geographically and to seek possible relationships. For this reason the authors have here and there called attention to foreign species or to larger groups which are similar in morphology to the local forms and which may later be discovered to have had a common origin. Such discoveries may have an important bearing on inter-regional migration and geologic history. The excessive splitting of genera and species and the resulting multiplication of names are often based either on characteristics whose stability and importance are unknown or on the mere assumption that geographically distant forms cannot be closely related. This practice may obscure natural relationships and indefinitely delay the recognition of inter-regional relationships. It appears that the provincial attitude of some systematists has, to an extent, concealed intercontinental faunal relationships[4] and thus made more difficult the work of students of world history as a whole.

The authors have given considerable thought to the general arrangement of the information accompanying each species in this monograph. The type locality, the depository of the type specimen, the geologic and geographic range of the species, and its occurrence in the Pliocene strata of southwestern San Diego County, should certainly be included. The original descriptions are included for the convenience of the reader because many of the publications in which they appeared are rare and, to many workers, not readily accessible.

Specific names printed in boldface type are for species which we have identified in the fauna of the San Diego formation in or near San Diego and which we consider to be valid members of that fauna. Specific names printed in standard type and enclosed in brackets [ ] are for species which have been

(3) Weller, J. M., "Paleontologist-Biologist and Geologist," Jour. Paleo., Vol. 22, No. 2, pp. 268-269, March, 1948.

(4) See remarks by C. A. Fleming (Trans. Roy. Soc. New Zealand, Vol. 79, Pt. 1, p. 128, 1951) concerning subgenera of *Pecten*. Also, "The Genus Pecten in New Zealand," New Zealand Geol. Surv., Paleo. Bull. 26, pp. 7-10, 1957.

reported from the San Diego formation in or near San Diego but of which we have not seen specimens. These we consider to be doubtful or invalid members of the fauna.

Species whose records of occurrence in the San Diego formation are equivocal, such as "San Diego-Purisima,"[5] are not included in the present paper unless substantiated by specimens or by published records definitely referable to the San Diego beds.

The references in the synonymy of the species, in general, have been restricted to the one containing the original description, to those containing illustrations of the type specimen (or of typical specimens), and to those in which the species is cited as occurring in Pliocene strata in the San Diego area. We also have included some references which, although not citing the species from the San Diego formation, contain information especially useful to others interested in the present faunal study. Additional references pertinent to the general discussion of the species are placed as footnotes. This system of citation of references is in general similar to that in the work of Anderson and Hanna[6].

Descriptions of families, genera, and subgenera are followed by the name of the author and the date when taken from works cited in the synonymy. Otherwise, the author and reference are cited. Where the author is not cited, the descriptions have been drawn up by the present authors. Some of the descriptions of the families and genera of Echinoidea in this work are taken verbatim from the excellent catalogue by H. L. Clark[7].

The systematic treatment of phyla of which we have made no special study is restricted to a brief summary based upon the literature, or upon information furnished us by others where so indicated in the text. A study of the Foraminifera has been entrusted to others and, if completed in time, it will be included in this memoir.

ABBREVIATIONS

Abbreviations following locality numbers or specimen numbers refer to the following institutions:

(ANSP) — Academy of Natural Sciences of Philadelphia.

(CAS) — California Academy of Sciences.

(LAM) — Los Angeles County Museum Invertebrate Paleontology.

(SD) — San Diego Society of Natural History.

(SU) — Stanford University.

(UC) — University of California (Berkeley).

(UCLA) — University of California at Los Angeles.

(USGS) — United States Geological Survey.

(USNM) — United States National Museum.

(5) See Smith, J. P., "Geologic Range of Miocene Invertebrate Fossils of California," Proc. Calif. Acad. Sci., Ser. 4, Vol. 3, pp. 161-182, April 5, 1912.

(6) Anderson, F. M., and Hanna, G. D., "Fauna and Stratigraphic Relations of the Tejon Eocene at the Type Locality in Kern County, California," Occ. Papers Calif. Acad. Sci., No. 11, pp. 1-249, pls. 1-16, figs 1-10 in text, March 18, 1925.

(7) Clark, H. L., "A Catalogue of the Recent Sea-Urchins (Echinoidea) in the Collection of the British Museum (Natural History)", (London), pp. i-xxviii, 1-250, pls. I-XII, 1925.

SYSTEMATIC DESCRIPTIONS

Phylum **COELENTERATA** Frey and Leuckart

Class **ANTHOZOA** Ehrenberg

Corals occur only rarely in Pliocene strata of California except in Imperial County, from which region seven species and five varieties were described by Vaughan[8]. In 1903, Vaughan described *Caryophyllia californica*[9] from supposedly Pliocene beds at San Pedro, California, which are now generally considered Pleistocene. *Astrangia coalingensis* Vaughan[10] was cited and illustrated in 1910 from strata now known to be of Pliocene age in San Joaquin Valley.

Nomland[11] in 1916 recorded seven species from the Pliocene of California and Oregon. Durham recorded one species[12] from the Pliocene of San Joaquin County, California, another [13] from probable late Pliocene in Humboldt County, and a third[14] from the Pliocene of Carmen Island in the Gulf of California. Durham[15] summarized the ranges of genera of fossil corals occurring in that region. More recently Durham and Barnard[16] dealt with the Recent species of stony corals of west American waters. The Order Scleractinia was treated by Vaughan and Wells[17] in 1943 and by Wells[18] in 1956.

The papers mentioned above contain additional references to literature dealing with corals which need not be mentioned here. Five genera, each represented by a single species, are known to occur in Pliocene beds in southwestern San Diego County.

Order **SCLERACTINIA** Bourne

Suborder **FAVIINA** Vaughan and Wells

Family **OCULINIDAE** Gray

Colonial; colony formation by extratentacular (or rarely intratentacular) budding. Corallites externally thickened by extensive, noncostate, granulated or smooth, dense (rarely vesicular) coenosteum. Septa exsert, formed by one fan system of simple trabeculae, margins minutely dentate, laterally granulose or spinose. Pali generally developed. Columella papillose, trabecular, or absent. Endothecal dissepiments, when developed, subtabular, thin, or replaced by stereome. (Wells, 1956.) Cretaceous to Recent.

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(8) Vaughan, T. W., "The Reef-Coral Fauna of Carrizo Creek, Imperial County, California, and its Significance," U.S. Geol. Surv., Prof. Paper 98-T, pp. 355-376, figs. 43-46, pls. 92-102, March 3, 1917.

(9) *Caryophyllia californica* Vaughan in Arnold, Mem. Calif. Acad. Sci., Vol. 3, p. 87, pl. 3, figs. 2, 2a, June 27, 1903. "Deadman Island, off San Pedro, California." "Geologic Horizon.—Pliocene."

(10) *Astrangia coalingensis* Vaughan in Arnold, U.S. Geol. Surv., Bull. 396, pp. 30, 34, 152, pl. 23, fig. 3, 1909 (issued January 15, 1910.

(11) Nomland, J. O., "Corals from the Cretaceous and Tertiary of California and Oregon," Univ. Calif. Publ. Bull. Dept. Geol., Vol. 9, No. 5, pp. 59-76, pls. 3-6, January 20, 1916.

(12) Durham, J. W., "A New Coral from the Pliocene of California," Jour. Paleo., Vol. 15, No. 3, pp. 278-279, figs. 1, 1a, 2, May, 1941.

(13) Durham, J.W., "Pacific Coast Tertiary and Cretaceous Corals," Jour. Paleo., Vol. 17, No. 2, pp. 196-202, figs. 1, 2, pl. 32, March, 1943.

(14) Durham, J. W., "1940 E. W. Scripps Cruise to the Gulf of California. Megascopic Paleontology and Marine Stratigraphy," Geol. Soc. America, Mem. 43, Pt. 2, pp. i-viii, 1-216, figs. 1-3, pls. 1-48, tables 1-10, August 10, 1950.

(15) Durham, J. W., "Corals from the Gulf of California and the North Pacific Coast of America," Geol. Soc. America, Mem. 20, pp. i-v, 1-68, figs. 1, 2, pls. 1-14, March 26, 1947. [A paper by D. F. Squires dealing with corals from the Gulf of California appeared recently (Bull. Amer. Mus. Nat. Hist., Vol. 118, Art. 7, pp. 367-432, text figs. 1-20, pls. 28-34, October 26, 1959).]

(16) Durham, J. W., and Barnard, J. L., "Stony Corals of the Eastern Pacific Collected by the Velero III and Velero IV," Allan Hancock Pac. Exped., Vol. 16, No. 1, pp. 1-110, pls. 1-16, August 18, 1952.

(17) Vaughan, T. W., and Wells, J. W., "Revision of the Suborders Families, and Genera of the Scleractinia," Geol. Soc. America, Spec. Paper No. 44, pp. i-xv, 1-363, figs. 1-39, pls. 1-51, tables 1-3, March 12, 1943.

(18) Wells, J. W., "Scleractinia," Treatise on Invertebrate Paleontology (Geol. Soc. America and the Univ. Kansas), Part F, Coelenterata, pp. F328-444, figs. 222-339, 1956.

Genus **ARCHOHELIA** Vaughan

Archohelia Vaughan, U.S. Nat. Mus., Bull. 103, Pt. 9, p. 352, July 11, 1919. "Type-species. —*Archohelia limonensis* Vaughan." —Vaughan and Wells, Geol. Soc. America, Spec. Paper No. 44, p. 181, March 12, 1943. "Genotype (original designation): *A. limonensis* Vaughan 1919."—Wells, Treatise Invert. Paleo. (Geol. Soc. America and Univ. Kansas), Pt. F, Coelenterata, p. F411, 1956. Type indicated as *A. limonensis* Vaughan.

TYPE SPECIES (by original designation): *Archohelia limonensis* Vaughan, 1919, p. 353, pl. 80, figs. 1, 1a, 1b, 2, 3. Cotypes from "Niveau *d*, Moin Hill, Port Limon," Costa Rica. "The geologic horizon seems to be Pliocene."

RANGE: Middle Cretaceous to late Pliocene. Atlantic and eastern Pacific.

ORIGINAL DESCRIPTION: *Archohelia* differs from *Oculina* solely by having a persistent axial corallite, whereas in *Oculina* there is no axial corallite. Pali or paliform teeth are present on all but the last cycle of septa. Columella trabecular, with some papillae on its upper surface. (Vaughan.)

REMARKS: Vaughan remarked that several Tertiary species of the eastern United States, which were referred to *"Astrohelia"*[19] Milne Edwards and Haime and to *Oculina* Lamarck, should be placed in *Archohelia*. About ten species of this genus are known.

Durham (1947, p. 7) indicated that the genus *Archohelia* occurs from Eocene to Miocene in the western United States. The present record from the San Diego formation extends the range of the genus into late Pliocene time in southern California.

Archohelia species

One well-preserved specimen of a coral and some imperfect ones were collected from Pliocene strata at Pacific Beach by Frank B. Tolman and the late Ernest H. Quayle. These were found in a light buff fossiliferous pebbly sandstone layer, 4 to 6 inches thick, 10 feet stratigraphically above the Eocene-Pliocene contact, just north of the mouth of the ravine cutting the terrace two hundred feet south of the lowest exposure of the contact. The beds also contained specimens of *Opalia*, echinoid spines, and Bryozoa.

A manuscript in our possession contains a description by Quayle of this coral. We have searched in vain for the specimens and illustrations of the Pliocene species described by Quayle. Lacking these we have reluctantly decided not to publish the description which he prepared. It is our conclusion that there can only be uncertainty concerning the identity of a species based upon a description but lacking specimens and illustrations.

Quayle considered this coral to be a new species of *Oculina* Lamarck, closely resembling *O. peruviana* Vaughan[20], an Eocene species from Peru.

He also compared it with *O. panzana* Loel and Corey[21], from early Miocene strata in San Luis Obispo County, California. After discussing Quayle's description with Dr. J. W. Durham, we agree with him that Quayle's coral probably is referable to *Archohelia* rather than to *Oculina*.

Family **RHIZANGIIDAE** d'Orbigny
(=*Astrangiidae* Verrill)

Colonial, ahermatypic. Colony formation by extratentacular budding from edge zone or stolon-like expansions of edge zone, polyps remaining organically connected or not, colonies commonly consisting of scattered corallites with no apparent connection, or united basally by coenosteum, or they form compact masses. Corallites small and low. Septa composed of one fan system of simple or compound trabeculae; irregular divergence of sclerodermites producing scattered lateral granulations and more or less irregular marginal dentations. Columella trabecular, rarely solid or absent. Endothecal dissepiments thin. (Wells, 1956.) Early Cretaceous to Recent.

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[19] The original spelling of this genus name is *Astrhelia*.

[20] *Oculina peruviana* Vaughan, in Bosworth, T.O., "Geology of the Tertiary and Quaternary Periods in the North-West Part of Peru," (Macmillan & Co., London), p. 127, pl. 21, figs. 2-5, 1922. "Near Negritos; Clavilithes Series." Eocene.

[21] *Oculina panzana* Loel and Corey, Univ. Calif. Publ. Bull. Dept. Geol. Sci., Vol. 22, No. 3, p. 275, pl. 65, figs. 1-3, December 31, 1932. "Vaqueros horizon, Lower Miocene only. Known only from the type locality, Carrizo Creek, west of the Carrizo ranch house, south end La Panza Mountains."

Genus ASTRANGIA Milne Edwards and Haime

Astrangia Milne Edwards and Haime, Comptes-Rendu Acad. Sci. Paris, Vol. 27, p. 496, November, 1848. No species cited. —Vaughan and Wells, Geol Soc. America, Spec. Paper No. 44, p. 177, 1943. "Genotype (Genolectotype, Milne Edwards and Haime, 1850): *A. michelini* Milne Edwards and Haime 1848."—Durham, Geol. Soc. America, Mem. 20, p. 25, 1947. "Genotype: *Astrangia michelinii* Milne Edwards and Haime."—Durham and Barnard, Allan Hancock Pac. Exped., Vol. 16, No. 1, p. 60, 1952. "Genotype: *Astrangia michelinii* Milne Edwards and Haime."—Wells, Treatise Invert. Paleo. (Geol. Soc. America and Univ. Kansas), Part F, Coelenterata, p. F408, 1956. Type indicated as *A. michelini* Milne Edwards and Haime.

TYPE SPECIES (designated by Milne Edwards and Haime, Palaeontogr. Soc. London, Vol. 3, Monogr. British Fossil Corals, Introduction, p. xliv, 1850): *Astrangia michelini* Milne Edwards and Haime. [Ann. Sci. Nat. Zool., Ser. 3, Vol. 12, p. 181, September, 1849. "Patria inconnue.—Coll. Michelin." For this species the authors cited Vol. 10, pl. 7, figs. 4, 4a, August, 1848. In the explanation to plate 7, however, these figures are referred to *"Oulangia Stokesiana";* and in volume 12, *Oulangia stokesiana* is cited on page 183, also with reference to Vol. 10, pl. 7, figs. 4, 4a. "Habite les Philippines (H. Cuming). —Coll. Stokes."]

RANGE: Middle Cretaceous to Recent. In the western United States, Oligocene to Recent. Recent in North, Central, and South America and the West Indies.

ORIGINAL DESCRIPTION: *G. Astrangia.* Diffère du genre précédent [*Rhizangia*] en ce que les polypiérites sont toujours unis entre eux par le base que est etalée, et que leur muraille est nue. (Milne Edwards and Haime.)

SUPPLEMENTARY DESCRIPTION: Encrusting, subplocoid, corallites united basally by thin peritheca, rarely solitary. All septa dentate. Columella papillary. Epitheca rarely developed. (Vaughan and Wells, 1943.)

REMARKS: The genus *Astrangia* is known to occur from Oligocene to Recent in western North America. Twenty-one species of this genus have been recorded from marine waters between San Luis Obispo Bay, California, and Zorritos, Peru, from the littoral zone to 91.5 meters (50 fathoms). Only one of these species occurs off southern California; the remainder occur in tropical and subtropical waters.

Astrangia coalingensis Vaughan was described from beds of late Pliocene age in the southern portion of the San Joaquin Valley, and *A. insignifica* Nomland was described from beds of late Pliocene age in Los Angeles. Several specimens questionably identified as the latter species were collected in the San Diego formation.

Astrangia cf. A. insignifica Nomland

Plate 19, Figures 1-4, 7

The following is a reference to typical *A. insignifica.*

Astrangia insignifica Nomland, Univ. Calif. Publ. Bull. Dept. Geol., Vol. 9, No. 5, p. 65, pl. 3, figs. 14, 15, January 20, 1916.

TYPE SPECIMEN: No. 12010, Invertebrate Paleontology Collection, University of California.

TYPE LOCALITY: "in upper Fernando formation, Pliocene, at corner of Fourth and Broadway streets, Los Angeles, California."

RANGE: Middle Pliocene in southern California.

OCCURRENCE IN THE SAN DIEGO FORMATION: LOS ANGELES COUNTY MUSEUM: Loc. 305, 2400 feet east and 1350 feet south of the northwest corner of Sec. 8, T.19S., R.2W., San Bernardino Base and Meridian (see U. S. Geol. Surv. topographic map, San Ysidro quadrangle, ed. 1943).

ORIGINAL DESCRIPTION: 'The material at hand consists of a single corroded specimen of slightly elliptical outline. It appears to have been connected to other corallites by a thin basal expansion. No costae are visible; this may perhaps be due to the worn condition of the specimen. Calice shallow. Septa in four cycles, thick, granulate, those of the third cycle fused to the second; the septa of the fourth cycle very small. Columella well developed, vesicular. Altitude of corallite, 2 mm.; maximum latitude, 8.3 mm. (Nomland.)

REMARKS: Six specimens belonging to the genus *Astrangia* were collected by G. P. Kanakoff at Loc. 305 (LAM), in the San Diego formation near the Mexican boundary. These specimens were examined by Dr. J. W. Durham, who identified them tentatively with *Astrangia insignifica* Nomland.

One specimen is 3 mm. high and its calice is 3.2 mm. in diameter. Another is 2.5 mm. high and the diameter of its calice approximately 4.3 mm. The type specimen of that species is not perfectly preserved, but according to Durham (1947, p. 29), there appear to be about 48 septa. The present specimens appear to have about the same number.

In addition to the original occurrence, *Astrangia insignifica* has been recorded by Soper and Grant[22] from late Pliocene strata at 5th and Hope streets in Los Angeles, California.

The imperfect state of preservation of the type specimen of *Astrangia insignifica* and the consequent uncertainty concerning some of its specific characters led Durham to describe somewhat similar specimens of a Recent coral from Ensenada, Lower California, under the name of *Astrangia lajollaensis*[23]. It is known to occur from San Luis Obispo Bay, California, to Santa Margarita Island, Lower California, Mexico, from shore to a depth of 53 meters (29 fathoms).

Suborder **CARYOPHYLLIINA** Vaughan and Wells

Family **CARYOPHYLLIIDAE** Gray

Solitary and colonial. Colony formation by extratentacular (rarely intratentacular) budding, forming phaceloid or dendroid colonies. Costae commonly covered by stereome or epitheca. Septa exsert. Columella formed by curled trabecular laths, solid, spongy or absent. Pali or paliform lobes common. Endothecal dissepiments developed in some groups. (Wells, 1956.) Jurassic to Recent.

Genus **PARACYATHUS** Milne Edwards and Haime

Paracyathus Milne Edwards and Haime, Ann. Sci. Nat., Ser. 3, Vol. 9, p. 318, May, 1848. Species cited: *Paracyathus stokesii* Milne Edwards and Haime, *P. desnoyersii* Milne Edwards and Haime, *P. procumbens* Milne Edwards and Haime, *P. aequilamellosus* Milne Edwards and Haime, *P. pedemontanus* Michelin, *P. turonensis* Milne Edwards and Haime, *P. caryophyllus* Lamarck, *P. brevis* Milne Edwards and Haime.—Vaughan and Wells, Geol. Soc. America, Spec. Paper No. 44, p. 206, 1943. "Genotype (genolectotype, Milne Edwards and Haime 1850): *P. procumbens* Milne Edwards and Haime, 1848. Eocene (Parisian). Hauteville (la Manche)."—Wells, Treatise Invert. Paleo. (Geol. Soc. America and Univ. Kansas), Part F, Coelenterata, p. F424, 1956. Type indicated as *Paracyathus procumbens* Milne Edwards and Haime.

TYPE SPECIES (designated by Milne Edwards and Haime, Palaeontogr. Soc. London, Vol. 3, Monograph of British Corals, Introduction, p. xv): "Typ. sp., *Paracyathus procumbens,* Milne Edw. and J. Haime, loc. cit., tab. x, fig. 6" [Ann. Sci. Nat., Ser. 3, Vol. 9, p. 320, pl. 10, figs. 6, 6a, 6b, May, 1848. "Fossile d'Hauteville." Eocene.]

RANGE: Eocene to Recent. Cosmopolitan. Bathymetric range, 13 to 1472 meters (7 to 805 fathoms). (Vaughan and Wells.)

DESCRIPTION: Solitary, turbinate, fixed. Pali opposite all but last cycle, merging with columellar papillae. (Wells.)

REMARKS: Corals of this genus are attached whereas *Heterocyathus* Milne Edwards and Haime and *Deltocyathus* Milne Edwards and Haime, also solitary, are free forms.

According to Vaughan and Wells about 40 species of *Paracyathus* are known. Three species have been described as fossils from west American Tertiary strata, and six species have been described as occurring in west American waters at the present time.

Paracyathus stearnsii Verrill

Plate 19, Figures 8-13

Paracyathus stearnsii Verrill, Proc. Boston Soc. Nat. Hist., Vol. 12, p. 393, May, 1869.—Durham, Geol. Soc. America, Mem. 20, p. 35, pl. 2, figs. 1, 2, 5, 6, March 26, 1947. Skidegate Inlet, Queen Charlotte Islands, British Columbia, to San Pedro, California, Recent.—Durham and Barnard, Allan Hancock Pac. Exped., Vol. 16, No. 1, p. 92, pl. 13, figs. 55a-c, August 18, 1952. Numerous records cited, British Columbia to Dewey Channel, Lower California, Recent.

TYPE SPECIMEN: Location unknown to the present authors.

TYPE LOCALITY: "Monterey, California; Robert E. C. Stearns."

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[22] Soper, E. K., and Grant, U. S., IV, "Geology and Paleontology of a Portion of Los Angeles, California," Bull. Geol. Soc. America, Vol. 43, No. 4, p. 1064, December 30, 1932.

[23] *Astrangia* (*Astrangia*) *lajollaensis* Durham, Geol. Soc. America, Mem. 20, p. 28, pl. 2, figs. 14, 15, 18, 20, 21, March 26, 1947. "Loc. A-3982 (Ensenada, Lower California, Mexico)." "Collected along beach" (p. 44).

RANGE: Middle Pliocene to Recent. Recent from Skidegate Inlet, Queen Charlotte Islands, British Columbia, to 8½ miles south of Dewey Channel, Lower California (between Natividad Island and Point San Eugenio), in 22 to 894 meters (12 to 489 fathoms); mostly occurring between 27 and 110 meters (15 and 60 fathoms).

OCCURRENCE IN THE SAN DIEGO FORMATION: LOS ANGELES COUNTY MUSEUM: Loc. 305, 2400 feet east and 1350 feet south of the northwest corner of Sec. 8, T.19S., R.2W., San Bernardino Base and Meridian (see U. S. Geol. Surv. topographic map, San Ysidro quadrangle, ed. 1943).

ORIGINAL DESCRIPTION: Corallum with an expanded base, above which it is somewhat constricted, and then expands rapidly to the edge of the broad, shallow cup, which is broad oval in form, the edge bent into slight lobes or undulations. Exterior with very numerous, prominent, subequal, scabrous costae, which extend from the summit to the outer edge of the base; on the basal portion three or five smaller ones often alternate with one more prominent; toward the summit some of them have a tendency to rise into crests; all are covered with several series of small, sharp granulations, similar to those on the sides of the septa. Five complete cycles of septa, with some small ones in some of the systems belonging to the sixth cycle, so that the whole number is about one hundred and twenty. The primary and secondary septa are considerably broader than the others, broadly rounded and somewhat exsert at summit, narrowed toward the base and divided into two or three unequal, broad, stout, paliform lobes, which are rough and lacerately spinulose at summit, and covered on the sides with coarse rough granulations. The septa of the succeeding cycles are successively narrower, thinner, and less exsert, with similar but smaller, rough, paliform teeth. Columella small, papillose, the papillae slender, prominent, lacerately spinulose at summit.

Height .60; diameter of narrowest part .38 by .50; diameter of cup .50 by .72; depth of cup .25. (Verrill.) [Dimensions in inches.]

REMARKS: A number of specimens, most of them imperfectly preserved, were collected by G. P. Kanakoff at Loc. 305 (LAM), near the Mexican boundary, associated with *Balanophyllia elegans* and *Dendrophyllia* cf. *D. oldroydi*. The specimens were identified by J. W. Durham and appear to be inseparable from the Recent *Paracyathus stearnsii,* which occurs in adjacent waters often at depths of 27 to 110 meters (15 to 60 fathoms). The calice of the largest specimen is 14.8 mm. in greater diameter and 11 mm. in lesser diameter.

Paracyathus stearnsii differs from the Recent *P. tiburonensis*[24] in possessing narrower costae, with fewer and coarser granules on top of the ridge.

The late Pleistocene *Paracyathus pedroënsis* Vaughan[25] was relegated to the synonymy of *P. stearnsii* by Durham and Barnard (1952).

Suborder **DENDROPHYLLIINA** Vaughan and Wells

Family **DENDROPHYLLIIDAE** Gray

Solitary and colonial, mostly ahermatypic. Colony formation by intra- and extratentacular budding. Wall formed by trabecular outer ends of septa and simple but very irregular synapticulae, irregularly porous, usually thick, irregularly costate or covered by reduced costal granulations. Porous, layered coenosteum in some colonial forms. Septa composed of one fan system of simple trabeculae, but trabeculae tend to be very irregular, commonly not united closely in plane of septum and vertically discontinuous with sclerodermites bending outward from septal plane, especially at periphery and near columella. Septa strongly granulated laterally, mostly smooth marginally except peripherally and centrally where irregular dentations occur, or wholly weakly dentate. Septa inserted following Pourtalès plan (Fig. 239), at least in early stages. Columella trabecular and spongy, or absent. Endothecal dissepiments thin and poorly developed. (Wells, 1956.) Late Cretaceous to Recent.

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(24) *Paracyathus tiburonensis* Durham, Geol. Soc. America, Mem. 20, p. 35, pl. 3, figs. 5, 6, March 26, 1947. "Loc. A 3664, depth 73 meters, southwest of Tiburón Island, Gulf of California."

(25) *Paracyathus pedroënsis* Vaughan, in Arnold, Mem Calif. Acad. Sci., Vol. 3, p. 88, pl. 3, figs 1, 1a, June 27, 1903. "San Pedro, California." "Pleistocene." (P. 46, species indicated as occurring at "Lumber Yard," Upper San Pedro, Pleistocene.)

KEY[26] TO THE GENERA OF DENDROPHYLLIIDAE

A. Solitary; corallum trochoid or subcylindrical (curved or straight) ..... *Balanophyllia*

B. Colonial; corallum dendroid; extratentacular budding ..... *Dendrophyllia*

Genus DENDROPHYLLIA de Blainville

Dendrophyllia de Blainville, Dict. Sci. Nat., Vol. 60, p. 319, 1830. Species cited (p. 320): *D*[*endrophyllia*]. *ramea* Linnaeus, *D. semiramea* de Haan, *D. cornigera* Lamarck, *D. rubeola* Quoy and Gaimard, *D. digitalis* [Blainville], *D. irregularis* [Blainville], *D. variabilis* [Blainville]. [The latter three species, fossil forms, were attributed to Guettard but since he had cited the species in the French language they are not acceptable in biological nomenclature. Blainville is considered to be the author of these species].—Vaughan and Wells, Geol. Soc. America, Spec. Paper 44, p. 237, March 12, 1943. "Genotype (genolectotype, Milne Edwards and Haime, 1850): *Madrepora ramea* Linnaeus 1758. Recent. Mediterranean and eastern North Atlantic."—Wells, Treatise Invert. Paleo. (Geol. Soc. America and Univ. Kansas), Part F, Coelenterata, p. F435, 1956. Type indicated as *Madrepora ramea* Linnaeus.

TYPE SPECIES (designated by Milne Edwards and Haime, Palaeontogr. Soc. London, Vol. 3, Monogr. British Fossil Corals, Introduction, p. liii, 1850): "Typ. sp., *Dendrophyllia ramea,* Blainville, loc. cit.; Milne, Edw., Atlas du Règne Animal de Cuvier, Zooph., pl. LXXXIII, fig. 1" [=*Madrepora ramea* Linnaeus, Syst. Nat., ed. 10, p. 797, 1758. "Habitat in O. Americano & Asiatico." Ref. to Pet. Gaz., t.76, fig. 7.— Also illustrated by Schmidt in Brehms Thierleben, ed. 2, Abt. 4, Bd. 2, p. 486, figs. A, B, 1884.—Döderlein, Mitteil. Zool. Station zu Neapel, Bd. 21, No. 5, p. 147, Taf. 9, figs. 90-92, September 6, 1913 (as *Dendrophyllia ramea*). Mediterranean, in 180 to 270 meters (98 to 148 fathoms), Atlantic at Madeira.]

RANGE: Eocene to Recent. Cosmopolitan. Bathymetric range, littoral zone to 1372 meters (0 to 750 fathoms). Temperature range, 11.2-27.3° C. (52-81° F.). (Vaughan and Wells.)

DESCRIPTION: Structures like *Balanophyllia,* but forming dendroid colonies by extratentacular budding from the edge-zone, the polyps remaining organically connected. Columella small. (Vaughan and Wells, 1943.)

REMARKS: About 25 species of this cosmopolitan genus have been described. Three species are known to occur at the present time in west American waters between southern California and the Gulf of California. One of these occurs in beds of Pliocene age in California. Woodring recorded an unidentified species of *Dendrophyllia* in beds of Pliocene age in the Santa Maria district, Santa Barbara County, California.

Dendrophyllia cf. *D. oldroydi* Faustino

Plate 19, Figures 5, 6, 15

The following are references to typical *D. oldroydi.*

Dendrophyllia oldroydi Faustino MS [misspelled Faustina] in I. S. Oldroyd, Stanford Univ. Publ. Univ. Ser. Geol. Sci., Vol. 1, No. 1, pl. 49, fig. 7, 1924. [No description.]—Faustino, Philippine Jour. Sci., Vol. 44, No. 3, p. 286, pl. 1, fig. 2, March, 1931. "Sunken Valley, between San Pedro and Redonda [Redondo], California, 200 fathoms; deep water off San Diego, California."—Durham, Geol. Soc. America, Mem. 20, p. 38, pl. 10, figs. 1, 9, March 26, 1947. "200 fms. off San Pedro, Calif. (holotype); numerous records by fishermen from 'deep water' off the Southern California coast; 100 fms. off Huntington Beach, California."

TYPE SPECIMEN: Holotype missing from Stanford University collection. Paratype, No. 5905, Department of Paleontology Type Collection, Stanford University; specimen illustrated by Faustino, 1931 (according to A. M. Keen, oral communication, 1957).

TYPE LOCALITY: "200 fathoms off San Pedro." California.

RANGE: Middle Pliocene to Recent. Recent, off San Pedro to San Diego, California, in 183 to 366 meters (100 to 200 fathoms).

OCCURRENCE IN THE SAN DIEGO FORMATION: LOS ANGELES COUNTY MUSEUM: Loc. 305, 2400 feet east and 1350 feet south of the northwest corner of Sec. 8, T.19S., R. 2W., San Bernardino Base and Meridian (see U. S. Geol. Surv. topographic map, San Ysidro quadrangle, ed. 1943).

DESCRIPTION: Colony high and arborescently branched. Two specimens are in the Stanford University collection; one is 30 centimeters high and 38 centimeters across in one direction, the other is 24 centimeters high with branches not so numerous and with a thick base. The branching is irregular and apparently takes place wherever there is opportunity. Budding takes place at the base of the branches and at the sides. The main stem of the first specimen, which is regarded as the type, is 1 centimeter, and

[26] Adapted from Vaughan and Wells, 1943.

the branches are about the same size. The base of the second specimen is 3 centimeters and the main branches 2 centimeters.

The corallites are subcircular, the largest are 1 centimeter in diameter, and project as much as 7 millimeters above the base. Wall perforate, covered externally with fine subequal costal striations, somewhat scabrous, corresponding to all septa. Corallites not very deep, with a jagged edge.

Septa in four complete cycles, often with narrow rudimentary septa corresponding to the fifth cycle. The form and arrangement of the septa are clearly shown in the figure.

Columella well developed, rather prominent, sometimes occupying about a third of the breadth of the corallite, composed of convoluted and contorted porous plates. (Faustino, 1931.)

REMARKS: Two imperfect branching specimens, tentatively assigned to this species, the larger specimen about 19 mm. long, and the larger calice about 10.5 mm. wide, were collected with specimens of *Balanophyllia elegans* Verrill at Loc. 305 (LAM) in southwestern San Diego County. Dr. J. W. Durham, University of California, considered these specimens to be comparable to *Dendrophyllia oldroydi*. The only other record of this species as a fossil is from beds of late Pliocene or early Pleistocene age in Humboldt County, California[27].

The solid character of the corallum, the varyingly exsert septa, the three sizes of costae, and the more rounded calices serve to separate *D. oldroydi* from *D. californica* Durham[28], which was described from off the west coast of Lower California. *Dendrophyllia cortezi* Durham and Barnard[29] was described from "South of Isla Partida, 70 fms." in the Gulf of California, and, according to its authors, "is separated from *D. oldroydi* Faustino by the dentate third cycle septa, by the longer and more slender calices, and by the upper margins of the calices being much less serrate in appearance."

Genus **BALANOPHYLLIA** Searles Wood

Balanophyllia Searles Wood, Ann. and Mag. Nat. Hist., Vol. 13, No. 81, p. 11, January, 1844. Sole species, *Balanophyllia calyculus* Searles Wood.—Vaughan and Wells, Geol. Soc. America, Spec. Paper No. 44, p. 236, March 12, 1943. "Genotype (monotypy): *B. calyculus* Wood 1844."—Durham, Geol. Soc. America, Mem. 20, p. 40, March 26, 1947. "Genotype: *Balanophyllia calyculus* Searles Wood."—Wells, Treatise Invert. Paleo. (Geol. Soc. America and Univ. Kansas), Part F, Coelenterata, p. F433, 1956. Type indicated as *B. calyculus* Wood.

TYPE SPECIES: (by monotypy): *Balanophyllia calyculus* Searles Wood, Ann. and Mag. Nat. Hist., Vol. 13, No. 81, p. 11, January, 1844. (Ref. to Mag. Nat. Hist., Vol. 3, p. 272, fig. 60d, 1830). "Sutton." "Red Crag." England. [Late Pliocene or Pleistocene]. [Illustrated by Milne Edwards and Haime, Palaeontogr. Soc. London, Vol. 3, Fossil Corals of Great Britain, Corals of the Crag, p. 9, pl. 1, figs. 3, 3a, 3b, 3c, 3d, 1850. Red Crag of Sutton, late Pliocene or early Pleistocene. — Neaverson, Strat. Paleo. (Macmillan and Co.: London), p. 28, fig. 4 (upper right), 1928.]

RANGE: Eocene to Recent. Recent world-wide, at depths of 0-1100 meters (0-601 fathoms) and in temperatures of 6.7-27.7° C. (44-82° F.), according to Vaughan and Wells (1943). In the western Americas from British Columbia to La Plata Island, Ecuador, and the Galapagos Islands, intertidal zone to 605 meters (331 fathoms), usually in about 91 meters (50 fathoms).

DESCRIPTION: Simple, solitary, conical corals, curved or straight, attached by base; septa very numerous, closely crowded and partly fused together; columella spongy; epitheca often present, structure porous; costae on exterior corresponding to the septa. (Adapted from Vaughan and Wells.)

REMARKS: About 50 species of this genus are known according to Vaughan and Wells. Two species have been described from Eocene strata and two from Oligocene strata in western North America. To this record of fossil forms we add the occurrence of a species from beds of Pliocene age in San Diego. Five species of *Balanophyllia* are known to occur at the present time in west American marine waters between British Columbia and Ecuador.

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(27) *Dendrophyllia oldroydi* Faustino?, Durham, Jour. Paleo., Vol. 17, No. 2, p. 201, pl. 32, fig. 1, March, 1943. "Loc. A3770, late Pliocene or Pleistocene of Humboldt County, California. Exposed in road cut along U. S. Highway 101, 1.5 miles north of bridge across Little River at Little River Beach State Park, from a highly fossiliferous gravel lense in loose sand."

(28) *Dendrophyllia californica* Durham, Geol. Soc. America, Mem. 20, p. 37, pl. 10, figs. 2, 6, March 26, 1947. "27°52′ N. Lat., 114°54′45″ W. Long. Taken on a rock cod line in 23 fms."

(29) *Dendrophyllia cortezi* Durham and Barnard, Allan Hancock Pac. Exped., Vol. 16, No. 1, p. 102, pl. 16, figs. 66a, 66b, August 18, 1952.

Balanophyllia elegans Verrill

Plate 19, Figures 14, 19-21; Plate 24, Figures 4, 5, 8, 13, 15-17

Balanophyllia elegans Verrill, Bull. Mus. Comp. Zool., Vol. 1, No. 3, p. 44, January, 1864.—Verrill, Trans. Connecticut Acad. Arts and Sci., Vol. 1, pp. 511-512, pl. 10, fig. 3, 1870. Puget Sound to Monterey, California, Recent.—Durham, Geol. Soc. America, Mem. 20, p. 41, pl. 1, figs. 7, 8, 11, 12; pl. 10, figs. 3, 4, text fig. 2A, 1947. British Columbia to Point Conception and the Channel Islands, California, low tide to 160 fathoms, Recent.—Durham and Barnard, Allan Hancock Pac. Exped., Vol. 16, No. 1, p. 99, pl. 14, figs. 62a-c, 1952. British Columbia to northwest of Cortes Bank, west of San Diego, California, in 36-321 fathoms, Recent.

TYPE SPECIMEN: Location unknown to the present authors.

TYPE LOCALITY: "Crescent City and Mendocino, California; A. Agassiz."

RANGE: Middle Pliocene to Recent. Recent from British Columbia, Canada, to Punta Santo Tomas[30], Lower California, Mexico, intertidal zone to 587 meters (321 fathoms), but usually abundant in less than 91 meters (50 fathoms).

OCCURRENCE IN THE SAN DIEGO FORMATION: LOS ANGELES COUNTY MUSEUM: Loc. 305, 2400 feet east and 1350 feet south of the northwest corner of Sec. 8, T.19S., R. 2W., San Bernardino Base and Meridian (see U. S. Geol. Surv. topographic map, San Ysidro quadrangle, ed. 1943). UNIVERSITY OF CALIFORNIA: Loc. A-8333, same locality as the preceding.

ORIGINAL DESCRIPTION: Corallum attached by a broad base, low, subturbinate. Calyx broad, oval, deep. Epitheca well developed, covering more than half the height of the wall, which is thin and very porous. Septa thin, forming five complete cycles, the principle ones a little exsert, strongly toothed at the summit, finely dentate below; those of the last order unite together near the columella, and are joined near their middle by those of the preceding order; columella porous, little developed. Height, .4 of an inch; greatest diameter of the calyx .48, shortest .4. Color of the living polyp, bright orange. (Verrill.)

REMARKS: Several hundred specimens referable to this species were collected by G. P. Kanakoff at Loc. 305 (LAM), near the Mexican boundary in southwestern San Diego County. The largest is about 20.8 mm. high with a calice 7 mm. in greatest diameter. These are all referable to the Recent species, *Balanophyllia elegans*. Five specimens, the largest 16 mm. in altitude and approximately 7 mm. in diameter, were collected by W. K. Emerson at the same locality (UC A-8333).

Durham (1947, p. 41) mentioned that northern littoral specimens of this species have nearly smooth septa but that the more southern forms in the same habitat have the septa ornamented with coarse granules. He further stated that specimens from deep water are thinner and more fragile, with the epitheca usually not well developed. Durham expressed the opinion (oral communication) that the elongate form of the present specimens might suggest that they lived at depths possibly between 46 and 366 meters (25 and 200 fathoms). Other fossils accompanying these corals suggest that the assemblage lived in comparatively shallow water.

Balanophyllia cedrosensis Durham (1947, p. 40, pl. 11, figs. 3, 5; text fig. 2B), described from near Cedros Island, was said to differ "from *B. elegans* by the greater constriction above the base, by its greater size, larger raised columella, and by the inner edges of all except the first two cycles of septa on *B. elegans* being markedly dentate. On *B. elegans* the septa slope to the floor of the calice, and the columella is not raised."

Vaughan and Wells (1943, p. 86) pointed out the close relationship between *Balanophyllia elegans* in the western Americas and *B. regia* Gosse in British waters, *B. verrucaria* Linnaeus[31] in the Mediterranean, and *B. capensis* Verrill[32] in South Africa.

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(30) Recorded by W. K. Emerson, Jour. Paleo., Vol. 30, No. 2, p. 394, March, 1956.

(31) *Madrepora verrucaria* Linnaeus, Syst. Nat., ed. 10, p. 793, 1758. "Habitat in M. Mediterraneo."—Milne Edwards and Haime, Ann. Sci. Nat., Ser. 3, Vol. 10, p. 85, pl. 1, figs. 6, 6a, August, 1848 (as *Balanophyllia verrucaria*). "Habite la Corse."—Milne Edwards and Haime, Hist. Nat. Corall., Vol. 3, p. 100, 1860 (as *Balanophyllia verrucaria*). "Habite la Corse." [The name of this species was erroneously cited as "*verrucosa*" by Vaughan and Wells].

(32) *Balanophyllia capensis* Verrill, Commun. Essex Inst., Vol. 5, p. 28, pl. 1, fig. 1; pl. 2, figs. 1, 1a, 1866. From Simon's Bay, Cape of Good Hope, 15 to 20 fathoms.

Phylum **BRYOZOA** Ehrenberg

A modern classification of this phylum by Bassler[33] appeared recently. Earlier, Canu and Bassler[34] published a report on late Tertiary and Quaternary Bryozoa of North America.

A number of specimens of Bryozoa were mounted on glass slides by W. D. Rankin during the segregation of foraminifera found in Pliocene strata at Pacific Beach, San Diego. These specimens were submitted to Dr. R. C. Bassler, Head Curator of the Department of Geology, United States National Museum, who kindly identified nine species. Dr. Bassler also identified, as to genus only, *Hippodiplosia* and *Membranipora* collected by the late E. H. Quayle.

Specimens of Bryozoa collected recently by George P. Kanakoff of the Los Angeles County Museum, from Pliocene strata in and near San Diego, were identified by Dr. John D. Soule, Allan Hancock Foundation, University of Southern California. He also studied the material which formed the basis of Bassler's list, finding one additional species, *Parasmittina trispinosa* (Johnston).

Table 1 lists the Pliocene species of Bryozoa from San Diego, as identified by Bassler and by Soule, the nomenclature according to Soule.

Dr. Soule's comments on this assemblage are summarized as follows.

Of the 31 species thus far definitely identified from the San Diego Pliocene, only three are not known in Recent waters. These are *Cheilopora grandis* Canu and Bassler, previously reported from the Eocene, and *Smittina discoidea* Canu and Bassler and *Stathmepora flabellata* Canu and Bassler, both previously listed only from the Pleistocene[35]. Of the remaining 28 species, so far as I know, only the following nine have previously been listed from the Pliocene:

Adeona violacea (Johnston)
Chapperia patula (Hincks)
Colletosia radiata (Moll)
Hippoporella gorgonensis Hastings
Hippothoa hyalina (Linnaeus)
Microporella ciliata (Pallas)
Parasmittina trispinosa (Johnston)
Porella porifera (Hincks)
Schizoporella cornuta (Gabb and Horn)

Of these nine only *Adeona violacea* (Johnston), found in present-day tropical waters, is not listed from the Pleistocene — unless the listing of *Adeona heckelii* Reuss refers to this species. (Canu and Bassler considered *A. violacea* a junior synonym of *A. heckelii;* but both Osborne and I disagree with this conclusion.)

The bathymetric ranges of the 28 Recent species are between low water and 490 meters (268 fathoms), most species occurring in less than 275 meters (150 fathoms).

The Pacific coast of North America south of the polar regions may be divided into three zoogeographical zones: (1) a cool temperate zone from Alaska to Point Conception, California, (2) a warm temperate zone from Point Conception to Magdalena Bay, Lower California, and (3) a tropic zone from Magdalena Bay to about 6° South Latitude. The 28 species of Bryozoa reported from the San Diego Pliocene and still extant have the following zonal distribution:

Hippothoa hyalina and *Parasmittina trispinosa* are truly cosmopolitan: they are found in abundance from the polar regions to tropical waters in both the Atlantic and the Pacific. Three species are exclusively tropical. Nine are tropical, warm temperate, and cool temperate. Ten are only warm and cool temperate. None are only cool temperate or polar. Thus the Pliocene Bryozoan fauna of San Diego appears to have been predominately warm temperate to tropical.

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(33) Bassler, R. S., "Bryozoa," [in] Treatise on Invertebrate Paleontology, (Geol. Soc. America and Univ. Kansas Press), Part G, pp. G1-G253, figs. 1-175, 1953.

(34) Canu, F., and Bassler, R. S., "North American Later Tertiary and Quaternary Bryozoa," U. S. Nat. Mus., Bull. 125, pp. i-vii, 1-302, figs. 1-38, pls. 1-47, July 16, 1923.

(35) See Soule, J. D., and Duff, M. M., "Fossil Bryozoa from the Pleistocene of Southern California," Proc. Calif. Acad. Sci., Ser. 4, Vol. 29, No. 4, pp. 87-146, November 5, 1957.

TABLE 1. PLIOCENE SPECIES OF BRYOZOA FROM SAN DIEGO

	Pacific Beach (CAS)	Loc. 414 (SD)	Loc. 415 (SD)	Loc. 417 (SD)	Loc. 107 (LAM)	Loc. 122 (LAM)	Loc. 305 (LAM)	Pleistocene	Recent
Adeona violacea (Johnston), 1847	.	.	.	.	.	.	x	.	x
Callopora corniculifera (Hincks), 1882	.	.	.	.	.	.	x	x	x
Cellaria diffusa Robertson, 1905	.	.	.	.	.	.	x	x	x
Cellaria mandibulata Hincks, 1882	x	.	.	.	.	.	x	x	x
Chapperia patula (Hincks), 1881	.	.	.	.	.	.	x	x	x
Cheilopora grandis Canu and Bassler, 1920	.	.	.	.	x	x	x	.	.
Coleopora gigantea (Canu and Bassler), 1923	.	.	.	.	.	.	x	x	x
Colletosia radiata (Moll), 1803	.	.	.	.	.	.	x	x	x
Conopeum commensale Kirkpatrick and Metzelaar, 1922	.	.	.	.	.	.	x	x	x
Crisia serrulata Osburn, 1953	x	.	.	.	.	.	.	x	x
Diaperoecia californica (d'Orbigny), 1852	x	.	.	.	.	.	x	x	x
Disporella californica (d'Orbigny), 1852	.	.	.	.	.	.	x	.	x
Eurystomella bilabiata (Hincks), 1882	.	.	.	.	.	.	x	x	x
Heteropora pacifica Borg, 1933	.	.	.	.	.	.	x	.	x
Hippodiplosia sp.	.	x	x	x	.	.	.	.	.
Hippopodinella adpressa (Busk), 1854	.	x	x	.	.	x	x	x	x
Hippoporella gorgonensis Hastings, 1930	.	.	.	.	.	.	x	x	x
Hippothoa hyalina (Linnaeus), 1767	x	.	.	.	.	.	x	x	x
Lagenipora punctulata (Gabb and Horn), 1862	x	.	.	.	.	.	x	x	x
Membranipora sp.	.	x	.	.	.	.	.	.	.
Microporella californica (Busk), 1856	.	x	.	.	.	.	x	x	x
Microporella ciliata (Pallas), 1766	.	.	.	.	.	.	x	x	x
Microporella umbonata (Hincks), 1884	.	.	.	.	.	.	x	x	x
Mucronella major (Hincks), 1884	.	.	.	.	.	.	x	x	x
Parasmittina trispinosa (Johnston), 1825	x	.	.	.	.	.	x	x	x
Penetrantia sp.[36]	.	.	.	.	.	.	x	x	.
Porella porifera (Hincks), 1884	.	.	.	.	.	.	x	x	x
Reginella mucronata (Canu and Bassler), 1923	x	.	.	.	.	.	x	x	x
Rhynchozoon rostratum (Busk), 1856	.	.	.	.	.	.	x	x	x
Schizoporella cornuta (Gabb and Horn), 1862	.	x	.	.	.	.	x	x	x
Smittina discoidea Canu and Bassler, 1923	x	.	.	.	.	.	.	x	.
Stathmepora flabellata Canu and Bassler, 1923	x	.	.	.	.	.	.	x	.
Thalamoporella californica (Levinsen), 1909	.	.	.	.	.	.	x	x	x
Tubulipora tuba (Gabb and Horn), 1862	x	.	.	.	.	.	x	x	x

(36) This record of a ctenostome Bryozoan is based upon galleries riddling fragments of shells to which Bryozoa are attached.

The Bryozoa recorded in the present paper are from the following localities.

CALIFORNIA ACADEMY OF SCIENCES: Pacific Beach; W. D. Rankin, collector.

LOS ANGELES COUNTY MUSEUM:

LOCALITY 107. — 100-foot bluff with scattered concretions, in the clay quarry at the end of Arroyo Drive, San Diego; G. P. Kanakoff, collector.

LOCALITY 122. — 20 to 30 feet below the end of Loring Street, Pacific Beach.

LOCALITY 305. — 2400 feet east and 1350 feet south of the northwest corner of Sec. 8, T.19S, R. 2W., San Bernardino Base and Meridian (see U. S. Geol. Surv. topographic map, San Ysidro quadrangle, ed. 1943); G. P. Kanakoff, collector.

SAN DIEGO SOCIETY OF NATURAL HISTORY:

LOCALITY 414. — Coarse conglomerate layer with a limy matrix, barnacle reef in the first road cut on Euclid Avenue south of University Avenue, where the road curves to the left as it enters Las Chollas Valley, San Diego; E. H. Quayle, collector. [= Loc. 308 (UCLA).]

LOCALITY 415. — Oyster layer in a building excavation at the southeast corner of India and Upas streets, San Diego; E. H. Quayle, collector. [=Loc. 309 (UCLA).]

LOCALITY 417. — The second ravine north of Loc. 331 (SD) and the fifth ravine north (about 1/4 mile north) of the Mexican boundary, at west face of terrace 3/4 mile east of coast, the ravine debouching near the north end of a willow patch. Lower conglomerate well consolidated and richly fossiliferous; E. H. Quayle, collector. [= Loc. 312 (UCLA).]

Phylum **BRACHIOPODA** Duméril

Brachiopoda are known to occur from early Cambrian to Recent. They are primarily shallow-water dwellers, becoming less abundant in deeper water, but they have been recorded from a depth of 5,477 meters (2,995 fathoms). The largest number of species live in the warmer seas.

The west American Cenozoic Brachiopoda have been discussed and illustrated in a monograph by the present authors[37], where references may be found (p. 10) to many of the important works dealing with their classification, morphology, and distribution. The west American Pliocene forms were classified in 3 orders, 5 families, 7 genera, and 20 species and subspecies. Five species and subspecies are represented in the Pliocene strata at San Diego. Many of the late Cenozoic species in western North America are represented by closely related forms in beds of approximately the same age in Japan[38].

Mattox[39] recently discussed the ecologic occurrences of brachiopod communities in the waters about Santa Catalina Island off southern California.

Class **INARTICULATA** Huxley

Order **ATREMATA** Beecher

Superfamily **LINGULACEA** Waagen[40]

Family **LINGULIDAE** Gray

Attenuate, sub-quadrate or spatulate, almost equivalved Lingulacea, with a more or less long, tubular, flexible pedicle. Muscles highly differentiated and consisting of six pairs, two adductors, and four of sliders or adjustors. (Schuchert in Eastman's ed. of Zittel's text-book of Paleo., 1913.) Ordovician to Recent.

Genus **GLOTTIDIA** Dall

Glottidia Dall, Amer. Jour. Conch., Vol. 6, Pt. 2, p. 157, October 6, 1870. "Type. *Glottidia albida*, Dall. Pl. 8, fig. 1-6."—Thomson, New Zealand Board Sci. and Art, Manual No. 7, p. 128, 1927. "Genotype.—*Lingula albida* Hinds," fig. 36 (a, b).—Hertlein and Grant, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 3, p. 10, November 4, 1944. "Type of the genus (by original designation).—*Glottidia albida* Hinds."

TYPE SPECIES (by original designation): *Glottidia albida* Hinds.

RANGE: Late Eocene to Recent. Recent in western America from Monterey Bay, California, to Peru. Also Caribbean.

ORIGINAL DESCRIPTION: Shell linguiform, elongate, pedunculated; general characters as in *Lingula*. Neural valve provided internally with two sharp narrow incurved laminae, diverging from the beak and extending about one-third the length of the shell; anterior extremities of the laminae about

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(37) Hertlein, L. G., and Grant, U. S., IV, "The Cenozoic Brachiopoda of Western North America," Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 3, pp. i-vi, 1-236, figs. 1-34, pls. 1-21, November 4, 1944.

Two later American works dealing with the Brachiopoda as a whole but with emphasis on classification, morphology, and distribution are: Cooper, G. A., [in] "Index Fossils of North America" by Shimer, H. W., and Shrock, R. R., (John Wiley & Sons, Inc., New York), Brachiopoda, pp. 277-365, pls. 105-143, 1944; Moore, R. C., Lalicker, C. G., and Fischer, A. G., "Invertebrate Fossils," (McGraw-Hill Book Co., Inc., New York), Brachiopoda, pp. 197-267, fig. 6(1-40), 1952.

(38) See Hatai, K. M., "The Cenozoic Brachiopoda of Japan," Sci. Repts. Tohoku Imper. Univ., Sendai, Japan, Ser. 2 (Geol.), Vol. 20, pp. 1-413, pls. 1-12, figs. 1-25, in text, 1940.

(39) Mattox, N., "Observations on the Brachiopod Communities near Santa Catalina Island," Essays in the Natural Sciences in Honor of Captain Allan Hancock on the Occasion of his Birthday July 26, 1955 (Univ. South. Calif. Press, Los Angeles), pp. 73-86, figs. 1-5, November 8, 1955.

(40) Cited as "Superfamily 2. Lingulacea. Waagen" by Schuchert in Eastman's edit. of Zittel's Text-Book of Palaeo., Vol. 1, p. 306, 1896. Waagen (Palaeo. Indica, Ser. 13, Vol. 1, Pt. 4, Fasc. 5, 1885) stated (p. 751), "a suborder for which I shall introduce the name of 'Lingulacea' or 'Mesokaulia'." P. 754, "Sub-Order: Mesokaulia sive Lingulacea." There is also a "Division" Lingulaceae of Bowditch, 1822, and "Fam. 1. *Lingulacea*" of Menke, 1830.

midway between the mesial line and the margin. Haemal valve with a mesial septum of about the same length extending forward from the beak. Anterior adductor impression rounded, separated by a faint mesial ridge, faintly impressed. Scar of the post adductor close in the cavity of the beak, rounded. No other evident scars. Shell smooth, perforate or imperforate. (Dall.)

REMARKS: We can add nothing to Morse's[41] remarks concerning the distinction between *Glottidia* and *Lingula* which follow:

"Aside from the internal structure of the dorsal and ventral shell, the form of the protegulum, the presence of gill ampullae, the arrangement of the oblique muscles, and the more anterior position of the coelomic cavity, I found that in *Glottidia* the setal tubes were not formed, though the lateral setae assume a vertical position when partially buried in the sand, as in *L. lepidula;* the sand tube is much more complete and symmetrical and in alcohol is retained on the peduncle, while in *L. lepidula* the sand tube becomes detached. In general behavior, however, the two forms are almost precisely alike. Charles Schuchert ('97), in considering the enormous period in geological history occupied by the Lingulidae, says the only change observable is that in the ancient forms the viscera occupy a little more and the brachia a somewhat less space than in the later forms. *Glottidia* by these characters is a more ancient type."

Glottidia, so far as known, is confined to the two sides of the Americas. It is known to occur from late Eocene to Recent in the eastern Pacific and from Miocene to Recent in the western Atlantic. Four species have been described living in west American waters and one in the Caribbean. Only one species has been recorded from beds of Pliocene age in western North America.

Schuchert mentioned that inarticulate Brachiopoda of shallow and littoral zones are found in comparatively warm water. The maximum depth at which *Glottidia* has been reported is 110 meters (60 fathoms); but as stated by Schuchert, "the immediate shoreline, and often the estuarine bays and deltas, will be indicated especially by the large lingulids embedded in muds and sands with an otherwise sparse fauna." They are therefore generally considered indicators of shorelines. Morse pointed out that the empty shells of *Glottidia* are delicate and light and unless covered by sediment are likely to be carried away by even a slight current.

Glottidia albida Hinds

Plate 19, Figures 17, 18, 23-25

Lingula albida Hinds, Voy. Sulphur, Zool., Moll., Pt. 3, p. 71, pl. 19, fig. 4, 1844 (date cited as January, 1845 on cover of No. 8, Moll., Pt. 3).—Cooper, Calif. State Mining Bureau, 7th Ann. Rept. State Mineralogist, p. 246, 1888. "San Diego well," Pliocene.

Glottidia albida Hinds, Dall, Proc. Calif. Acad. Sci., Vol. 5, p. 296, 1874. "Well at San Diego." "Pliocene."—Arnold, Mem. Calif. Acad. Sci., Vol. 3, p. 94, 1903. "San Diego well (Hemphill)," Pliocene.—Hertlein and Grant, Mem. San Diego Soc. Nat. Hist., Vol. 2, p. 48, Dall's record of well at San Diego; p. 59, "excavations along India Street, particularly at the corner of Upas Street," 1944.—Hertlein and Grant, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 3, p. 12, pl. 1, fig. 5 (San Diego, Recent), 6 (reproduction of original figure), 7 (Redondo Beach, Calif., Recent), text figs. 1a-1c (Recent), 1944. Page 14, "San Diego well"; "India and Upas streets"; "Soledad Mountain," Pliocene. Also cited from other localities in and near San Diego.

TYPE SPECIMEN[42]: [?] No. ZB.1, Department of Paleontology, British Museum (Natural History).

TYPE LOCALITY: "Bay of Magdalena, [Lower] California. In seven fathoms, among sandy mud."

RANGE: ?Late Eocene to Recent. Recent from Monterey Bay, California, to Acapulco Bay, Mexico, from the intertidal zone to 110 meters (60 fathoms) or perhaps to 146 meters (80 fathoms).

OCCURRENCE IN THE SAN DIEGO FORMATION: San Diego well, Balboa Park (Dall; Cooper; Arnold; Hertlein and Grant). CALIFORNIA ACADEMY OF SCIENCES: Loc. 957, upper beds of Pliocene section, 5 to 15 feet beneath overlying Pleistocene at Pacific Beach; Loc. 1181, gulch on south slope of Soledad Mountain about ⅓ mile west of Rose Canyon; Loc. 1399, in

(41) Morse, E. S., "Observations on Living Brachiopods," Mem. Boston Soc. Nat. Hist., Vol. 5, No. 8, pp. 313-386, pls. 39 61, 1902 (see especially p. 317).

(42) Dr. Helen M. Muir-Wood of the British Museum (Natural History), Department of Paleontology, furnished us the following information pertaining to the type specimen of this species. "The type specimen of *Glottidia albida* (Hinds) is more difficult since there is nothing in the 'Voyage of the Sulphur' Report to indicate where the figured specimen is located. Hinds mentioned that he had used the Cuming collection specimens in preparing his report and it seems probable that the Cuming specimen which was figured by Reeve, Conch. Icon. vol. 13, Mon. *Lingula,* 1862, plate 1, fig. 4, may be the same as Hinds' specimen. The pedicle in this specimen is no longer preserved and the two valves have been separated at some earlier date and attached in a rather broken condition to cardboard. Cuming's specimen corresponds quite well in size with Hinds' figure. There is no label with this specimen to show whether it was used by Hinds or not. The number of this specimen preserved in the Department of Paleontology is ZB.1."

bluff 100 to 200 yards south of Eocene-Pliocene contact at Pacific Beach; Loc. 1401, first canyon west of Rose Canyon on south slope of Soledad Mountain; Loc. 28880, road cut 0.1 mile east of Euclid Avenue on north side of Market Street, in Las Chollas Valley, San Diego; Loc. 28893, corner of India and Upas streets, San Diego. LOS ANGELES COUNTY MUSEUM: About 50 feet northeast from north end of quarry at Loc. 107 [=clay quarry at end of Arroyo Drive]; Loc. 305, 2400 feet east and 1350 feet south of northwest corner of Sec. 8, T.19S., R.2W., San Bernardino Base and Meridian (see U. S. Geol. Surv. topographic map, San Ysidro quadrangle, ed. 1943). SAN DIEGO SOCIETY OF NATURAL HISTORY: Loc. 5, south slope of Soledad Mountain, same locality as Loc. 1181 (CAS); Loc. 34, northeast corner of India and Thorn streets, San Diego; Loc. 80, south slope of Soledad Mountain, same locality as Loc. 1181 (CAS); Loc. 417, fifth ravine north of Mexican boundary, about ¼ mile north of boundary, at west face of terrace about ¾ mile east of coast. UNIVERSITY OF CALIFORNIA AT LOS ANGELES: Loc. 296, street cut on northwest side of Fairmount Avenue, 0.4 mile north of intersection with Broadway, San Diego [=Loc. 400 (SD)]; Loc. 302 [=Loc. 28880 (CAS); Loc. 408 (SD)]; Loc. 309, oyster bed in building excavation at southeast corner of India and Upas streets, San Diego [=Loc. 415 (SD)]; Loc. 312, second ravine north of Loc. 294 (UCLA), and fifth ravine north of Mexican boundary, about ¾ mile east of coast, ravine debouching near north end of willow patch [=Loc. 417 (SD)]; Loc. 2359, south slope of Soledad Mountain, in soft fine-grained sandstone outcropping in small canyon parallel to and about 0.2 mile west of mouth of Rose Canyon and 0.4 mile north of Garnet Avenue. This locality is 2.6 miles S.40°E. of triangulation station on Soledad Mountain.

ORIGINAL DESCRIPTION: Testâ oblongâ, laevi, complanatâ, anticè truncatâ, ubiquè albidâ; pediculo brevi, cylindraceo. (Hinds.)

REMARKS: *Glottidia albida* is easily recognized by its elongate boat-shaped form and thin, smooth, shiny, yellowish or cream-colored shell. Recent specimens are sometimes ornamented with brown streaks along the sides of the shell.

Specimens of this small brachiopod, often about 15 to 20 mm. in length, occur at many localities in the San Diego formation. Perfect specimens, however, are not easily recovered because of the fragile nature of the shell. Excellent specimens, the largest approximately 20 mm. in length and 9.5 mm. in width, were collected by J. F. Arndt about 50 feet northeast of Loc. 107 (LAM).

The shell is less pointed posteriorly and the internal laminae are more divergent in this species than in *Glottidia palmeri* Dall[43], which occurs in the Gulf of California. The shell of *Glottidia audebarti* Broderip[44] also is more pointed posteriorly than that of *G. albida,* and in Recent specimens the distal half is colored bright green. Juvenile specimens of *Glottidia albida* are somewhat similar to those of *Glottidia semen* Broderip[45]. Judging from the description and illustrations, it appears that the shell of *G. semen* is smaller and thicker and the anterior end is straighter in outline.

Specimens from well cores from Pliocene strata in San Joaquin County, California, have been referred by us to the present species. Some of these have the posterior end somewhat more pointed than that of typical *Glottidia albida,* but this may be due to imperfect preservation. An imperfect specimen from a well core from the lower portion of the Kreyenhagen formation of late Eocene age in Fresno County, California, was questionably referred to *G. albida* by the present authors, but perfect specimens from beds of that age may show differences from Recent specimens.

Woodring[46] mentioned the rare occurrence of "*Glottidia* cf. *G. albida* (Hinds)" in the Cebada member of the Careaga sandstone in the Santa Maria district in southern California. Many species in the associated fauna also occur with *Glottidia albida* in the Pliocene beds at San Diego.

Glottidia albida is an inhabitant of fine sand and mud bottoms, where it affixes itself by its pedicle. It appears to be somewhat tolerant of salinity, and it usually does not occur in coarse sand or in the densest muds. It has been recorded as occurring from intertidal flats to a depth of 110 meters (60 fathoms) and perhaps 146 meters (80 fathoms). Mattox (1955) recorded it from depths of 15, 27, and 82 meters (8, 15, and 45 fathoms) on sandy bottoms around Santa Catalina Island, California.

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(43) *Glottidia* (?*albida* var.) *palmeri* Dall, Amer. Jour. Conch., Vol. 7, Pt. 2, p. 77, November 2, 1871. "Habitat at the head of the Gulf of California on the Lower California side, opposite the mouth of the Colorado River; in sandy shelly mud at low water mark."—Hertlein and Grant, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 3, p. 17, pl. 1, fig. 10, text fig. 2, 1944. Earlier records cited. Gulf of California.

(44) *Lingula audebardii* Broderip, Proc. Zool. Soc. London for 1833, p. 125, March 12, 1834. "Hab. ad Insulam Punam. (Bay of Guayaquil)." "Mr. Cuming found this species, at about half-tide, in an extensive bottom of hard coarse sand, from four to six inches below its surface."—Hertlein and Grant, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 3, p. 16, pl. 1, figs. 2-4, 1944. Earlier records cited. Lower California to Peru (as *Glottidia audebarti*).

(45) *Lingula semen* Broderip, Proc. Zool. Soc. London for 1833, p. 125, March 12, 1834. "Hab. ad Insulam Platam Columbiae Occidentalis." "Dredged by Mr. Cuming in fine coral sand from a depth of seventeen fathoms."—Hertlein and Grant, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 3, p. 20, pl. 1, fig. 1, 1944 (as *Glottidia semen*). Earlier records cited.

(46) Woodring, W. P., in Woodring, W.P., and Bramlette, M. N., "Geology and Paleontology of the Santa Maria District California," U.S. Geol. Surv., Prof. Paper 222, pp. 48 (insert), 62, 1951.

He mentioned that it did not occur commonly, but he suggested that it may occur in colonies because one bottom sample from 82 meters (45 fathoms) contained 43 individuals in an area of two square feet.

Class **ARTICULATA** Huxley

Order **TELOTREMATA** Beecher

Superfamily **TEREBRATULACEA** Waagen[47]

Family **TEREBRATELLIDAE** King

Terebratulacea in which the lophophore up to the schizolophus stage has the cirri directed inwardly. The primary invagination of the lophophore in the schizolophus stage is occupied by a median septum. The loop in the higher genera develops both from the cardinalia and the median septum, but may ultimately free itself from the latter, and the septum may be partly or wholly resorbed. (Thompson, 1927.) Jurassic to Recent.

Elliott[48] recently discussed the geological distribution and the origin of the Terebratelloid Brachiopoda.

KEY TO THE GENERA OF TEREBRATELLIDAE

A. Generally wider than long; sulcate; generally multiplicate or smooth; foramen large.....*Terebratalia*

B. Generally longer than wide; anterior margin straight or with a slight sulcus; smooth, coarsely punctate; foramen small.....*Laqueus*

Genus **TEREBRATALIA** Beecher

Terebratalia Beecher, Trans. Connecticut Acad. Arts and Sci., Vol. 9, Pt. 2, p. 377, 1893. "Type. *Terebratula transversa* G. B. Sowerby." —Thomson, New Zealand Board Sci. and Art, Manual No. 7, p. 245, 1927. "Genotype. —*Terebratula transversa* Sowerby." —Hatai, Sci. Repts. Tohoku Imper. Univ., Sendai, Japan, Ser. 2 (Geol.), Vol. 20, p. 275, 1940. "Genotype:—*Terebratula transversa* Sowerby." —Hertlein and Grant, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 3, p. 117, 1944. "Type of the genus (by original designation). —*Terebratula transversa* Sowerby."

TYPE SPECIES (by original designation): *Terebratula transversa* G. B. Sowerby [Proc. Zool. Soc. London for 1846, p. 94. No locality cited. —Hertlein and Grant, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 3, p. 135, pl. 8, figs. 10, 15, 16; pl. 9, figs. 1, 2, 5-7; pl. 21, figs. 8, 9, 1944 (as *Terebratalia transversa*). Earlier records cited, Miocene to Recent. Recent from the Shumagin Islands, Alaska, to Ensenada, Lower California, Mexico.]

RANGE: Oligocene to Recent from Japan to Lower California, Mexico. Recent in splash pools above high tide and at depths of 1463 meters (800 fathoms), but most of the species live at depths less than 183 meters (100 fathoms).

DESCRIPTION: Shell large, generally wider than long, sulcate, test smooth or more generally multiplicate. Beak short, suberect, beak-ridges sharp, with planareas on each side, foramen large, mesothyrid, attrite and generally much worn, incomplete or occasionally complete. Hinge-teeth supported by dental plates, which are small, recessive ventrally, and sometimes almost obsolete, pedicle-collar short, sessile. Cardinalia strong, somewhat variable, characterized by a callous deposit between the socket-ridges in the umbonal region, with which the septum unites; the crural bases are closely applied to the socket-ridges in the type species, and run back to join the callous deposit, but in other species are separated from the socket-ridges by partially excavate external hinge-plates, or may be much swollen. Cardinal process variable in size, fused with the callous deposit. Septum generally stout, but very low posteriorly. Loop generally with a narrow ribbon, long, reflected, and united to the septum by a narrow connecting

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[47] Cited as "Superfamily 2. Terebratulacea Waagen" by Schuchert in Eastman's edit. of Zittel's Text-Book of Palaeo., Vol. 1, p. 325, 1896. Waagen (Palaeo. Indica, Ser. 13, Vol. 1, Pt. 4, Fasc. 2, p. 447, 1883) proposed the "Sub-Order: Kampylopegmata, sive Terebratulacea, comprising the families: *Terebratulidae, Thecideidae, Rynchonellidae, and Stringocephalidae.*" There is also "Fam. 2. Terebratulacea" of Menke, 1830.

[48] Elliott, G. F., "On the Geographical Distribution of Terebratelloid Brachiopods," Ann. and Mag. Nat. Hist., Ser. 12, Vol. 4, No. 40, pp. 305-334, figs. 1-5, 1951; "The origin of the Terebratellacea (Brachiopoda)," Ann. and Mag. Nat. Hist., Ser. 12, Vol. 10, No. 112, pp. 259-264, April, 1957.

band from the descending branches. The pedicle is short, and the foraminal edges and sometimes the dorsal umbo are generally much abraded. (Thomson, 1927.)

REMARKS: Thirteen species and subspecies of this genus were cited in our earlier paper (1944) as occurring in the Cenozoic of the northeast Pacific. Hatai (1940) cited ten species from the Cenozoic of Japan.

KEY TO THE SPECIES OF TEREBRATALIA

A. Mesial flexure on the pedicle valve concave, on the brachial valve convex
   a. Mesial flexure usually pronounced; ribs about 9 on typical form (occasionally as many as 24) ..... *occidentalis*
   aa. Mesial flexure usually very weak; ribs about 40 on typical form ..... *arnoldi*
B. Mesial flexure on the pedicle valve convex, on the brachial valve concave ..... *hemphilli*

Terebratalia arnoldi Hertlein and Grant

Plate 19, Figure 30

Terebratalia smithi Arnold, J. P. Smith, Proc. Calif. Acad. Sci., Ser. 4, Vol. 3, p. 170, 1912. "San Diego-Purisima." —J. P. Smith, Proc. Calif. Acad. Sci., Ser. 4, Vol. 9, No. 4, pp. 150, 151, 1919. "San Diego," Pliocene. —Hertlein and Grant, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 3, p. 133, 1944. "Pacific Beach, San Diego, between 100 and 200 meters south of the Eocene-Pliocene contact." Record by J. P. Smith also cited.

Not *Terebratalia smithi* Arnold, 1903.

Terebratalia arnoldi Hertlein and Grant, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 3, p. 119, pl. 11, figs. 1-3, 10-15, November 4, 1944.

TYPE SPECIMEN: No. 7313, Type Collection, Department of Geology, California Academy of Sciences.

TYPE LOCALITY: "From Loc. 27185 (Calif. Acad. Sci.), center of SW. ¼ of Sec. 23, T.3N., R.18W., S.B.B. & M., Ventura County, California (C. Leach, collector, December, 1931). Middle Pliocene."

RANGE: Middle Pliocene in California.

OCCURRENCE IN THE SAN DIEGO FORMATION: CALIFORNIA ACADEMY OF SCIENCES: Loc. 1399, in bluffs 100 to 200 yards south of Eocene-Pliocene contact at Pacific Beach. LOS ANGELES COUNTY MUSEUM: Loc. 308, 0.2 mile north of intersection of Harbor Boulevard and Tourmaline Street, Pacific Beach.

ORIGINAL DESCRIPTION: Shell resembling *Terebratalia occidentalis* Dall in general shape and ornamentation, but differing in having only a very slight development of a medial sulcus on the pedicle valve and fold on the brachial valve. The ribs increase by bifurcation and intercalation. Along the ventral margin of the pedicle valve of the type there are about forty ribs, but these are less in number on small specimens. Dimensions (of holotype): length, 41 mm.; width, approximately 42.3 mm.; convexity (of both valves), 22.4 mm. (Hertlein and Grant.)

REMARKS: A pedicle valve from the lower portion of the series of strata at Pacific Beach, comparable to *Terebratalia arnoldi,* measures 41 mm. in length, 39.3 mm. in width. The mesial basal portion of the valve is lacking, but on the remaining portion no trace of a mesial fold or sulcus is visible. The ratio of width to length is a little less than in typical specimens of *T. arnoldi,* but this specimen is quite similar to some of those of *T. arnoldi* from Pliocene beds in Tapo Canyon, Ventura County, California. Radial ribbing is present although imperfectly preserved on the present specimen. The lack of a mesial fold in this pedicle valve leads us to refer it to *T. arnoldi* rather than to *T. smithi* as was done in our earlier paper, 1944. Two eroded valves, the larger one 23.5 mm. in height, from Loc. 308 (LAM), are questionably referable to *T. arnoldi.*

Terebratalia smithi Arnold was described from strata on Deadman Island, San Pedro, California, originally believed to be of Pliocene age but now considered by some as Pleistocene. That species has a well-deveolped medial fold on the pedicle valve and sulcus on the brachial valve. It apparently is closely related to *Terebratalia hemphilli* and *T. transversa.* It has been recorded from several localities in beds of Pliocene age, but some of these occurrences may be referable to other species.

J. P. Smith reported *Terebratalia smithi* from the Pliocene beds at San Diego, but in collections from San Diego we have not seen any specimens certainly referable to that species. We are therefore inclined to refer Smith's record to *T. arnoldi,* although there is a possibility that it could refer to *T. hemphilli.*

Terebratalia arnoldi etchegoini Hertlein and Grant[49], described from the Etchegoin formation, of late Pliocene age, in the Coalinga district in the San Joaquin Valley, California, differs from the typical form in its smaller size, its often finer ribs, and its extremely variable and often distorted shape. This subspecies was reported recently [50] from Sonoma County, California, in beds of late Pliocene age probably equivalent to those of the lower portion of the Merced formation at its type locality.

An incomplete valve (UCLA coll.), collected by E. H. Quayle near the corner of India and Upas streets, San Diego, bears a faint medial sulcus similar to that of the *Terebratalia arnoldi* group. The preservation does not warrant a definite record, but, as mentioned in our earlier paper, the general appearance is suggestive of the subspecies *etchegoini.*

Terebratalia arnoldi quaylei Hertlein and Grant[51], described from the Santa Margarita formation, late Miocene, of San Luis Obispo County, California, differs from typical *T. arnoldi* in the decided development of a medial sulcus on the pedicle valve.

Some species described from beds of late Miocene and of Pliocene age in Japan[52] bear a strong resemblance to *Terebratalia arnoldi,* but their identity with the California form is not certain.

Terebratalia hemphilli Dall

Plate 19, Figures 26, 27

Terebratalia hemphilli Dall, Proc. U.S. Nat. Mus., Vol. 24, No. 1264, p. 561, pl. 40, figs. 8, 10, March 31, 1902.—J. P. Smith, Proc. Calif. Acad. Sci., Ser. 4, Vol. 9, No. 4, pp. 150, 151, 1919. "San Diego," Pliocene.—Hertlein and Grant, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 3, p. 123, pl. 9, figs. 3, 4 (copies of original figures); pl. 10, figs. 1, 2 (from Tapo Canyon, Ventura County, Pliocene), 1944. P. 124 "Market and Euclid streets, San Diego" and "Pacific Beach," Pliocene.

Terebratalia hemphillii Dall, Carson, Pan-Amer. Geol., Vol. 43, No. 4, p. 268, May, 1925. "San Diego fauna," Pliocene.

TYPE SPECIMEN: No. 108,495, United States National Museum.

TYPE LOCALITY: "Pliocene of Santa Barbara, between one-half and 1 mile inland from the sea, in Arroyo Buero on the Hope ranch; collected by J. Howard Wilson. U.S.N.M., 108,495."

RANGE: Middle Pliocene to late Pliocene or early Pleistocene in southern California.

OCCURRENCE IN THE SAN DIEGO FORMATION: San Diego, unlocalized (J. P. Smith; Carson). CALIFORNIA ACADEMY OF SCIENCES: Loc. 547, Pacific Beach; Loc. 28880, road cut 0.1 mile east of Euclid Avenue on Market Street, in Las Chollas Valley, San Diego. LOS ANGELES COUNTY MUSEUM: Loc. 122, 20 to 30 feet below end of Loring Street, Pacific Beach; Loc. 308, 0.2 mile north of intersection of Harbor Boulevard and Tourmaline Street, Pacific Beach (juvenile specimens); Loc. 311, embankment on Windsor Drive where Tourmaline Street would intersect if projected, Pacific Beach district [=Loc. 28884 (CAS)].

ORIGINAL DESCRIPTION: Shell substantially as figured, thin, rather compressed or not very convex; transverse, valves with low, flattish, ill-defined radial riblets, which, except near the beaks, become obsolete toward the middle of the valves. Mesial flexure shallow, broad mesially concave. Area narrow, ill-defined; foramen narrow, high, incomplete below; punctation fine and profuse. Alt. 30.0, lat. 33.0, diam. 12.0 mm. (Dall.)

REMARKS: *Terebratalia hemphilli* resembles *T. smithi* Arnold[53] in general characters but differs in that the mesial portions of the valves are usually smooth, only the lateral areas being radially sculptured; also the shell is usually broader and the foramen smaller. The present species also is similar to large smooth forms of *Terebratalia transversa* Sowerby, but it is generally larger and broader in

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(49) *Terebratalia arnoldi etchegoini* Hertlein and Grant, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 3, p. 122, pl. 10, figs. 5, 9-11, November 4, 1944. "From Loc. 189 (Southern Pacific Coll., Calif. Acad. Sci.), 600 feet southeast of northwest corner of Sec. 26, T.22S., R.16E., M.D.B. & M., in base of conglomerate above blue sandstone, Coalinga district, California; Etchegoin, Pliocene."

(50) Peck, J. H., Jr., Program of Geol. Soc. America Cordilleran Sec. Fifty-third meeting at Univ. Calif. at Los Angeles, April 19-20, 1957, p. 31; Bull. Geol. Soc. America, Vol. 68, No. 12, Pt. 2, p. 1841, 1957.

(51) *Terebratalia arnoldi quaylei* Hertlein and Grant, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 3, p. 122, pl. 17, figs. 1, 4, 7, November 4, 1944. "Loc. 1106 (Univ. Calif. at Los Angeles), three miles southwesterly on the south side and up the Nacimiento River from the Nacimiento Ranch house, well towards the head of a ravine northwest of 1,108-foot hill, in the NW ¼ of the SE ¼ of Sec. 13, T.25S., R.10E., M.D.B. & M., Bradley Quadrangle, San Luis Obispo County, California (Mr. and Mrs. E. H. Quayle, collectors, March, 1938). Santa Margarita formation, upper Miocene. Associated with *Pecten (Lyropecten) estrellanus* Conrad."

(52) See *Dallinella smithi* Arnold, Hatai, Sci. Repts. Tohoku Imper. Univ., Sendai, Japan, Ser. 2 (Geol.), Vol. 20, p. 299, pl. 8, figs. 39, 40, 1940. Earlier records cited, "Miocene to Pliocene."

(53) *Terebratalia smithi* Arnold, Mem. Calif. Acad. Sci., Vol. 3, p. 93, pl. 17, fig. 9, 1903. "Pliocene of Deadman Island," San Pedro, California.—Hertlein and Grant, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 3, p. 133, pl. 10, figs. 4, 6-8, 1944. Earlier records cited. Pliocene of central and southern California.

outline. An unusually large specimen in the collection at Stanford University measures 64 mm. in length, 58 mm. in width, and approximately 40 mm. in convexity. There is considerable variation in the degree of convexity or concavity as well as in the sculpture of the valves of this species.

A specimen from Loc. 28880 (CAS), on Market Street east of Euclid Avenue, San Diego, is referable to *Terebratalia hemphilli*. A single incomplete, almost smooth brachial valve (pl. 19, fig. 27), collected by Henry Hemphill from Pliocene beds at Pacific Beach appears to be referable to this species, but it could equally well be referable to *Terebratalia transversa* Sowerby. A well-preserved and only slightly imperfect pedicle valve (pl. 19, fig. 26), from Loc. 122 (LAM), Pacific Beach, bears fine radial riblets over the entire outer surface. It is 38.9 mm. in length, 38 mm. in width, and approximately 13.4 mm. in convexity (one valve). Two juvenile specimens, apparently referable to *T. hemphilli*, were collected by G. P. Kanakoff at Loc. 308 (LAM), 0.2 mile north of the intersection of Harbor Boulevard and Tourmaline Street, Pacific Beach.

Specimens typical of this species in the collections of the University of California at Los Angeles from Browns Canyon in the Newhall Quadrangle, Los Angeles County, are associated with typical Pliocene mollusks that also occur in the Pliocene beds at San Diego, including *Ostrea vespertina* Conrad, *Pecten bellus* Conrad, *Pecten healeyi* Arnold, and *Pecten opuntia* Dall.

Terebratalia occidentalis Dall

Plate 19, Figures 16, 22, 31

Terebratella occidentalis Dall, Proc. Calif. Acad. Sci., Vol. 4, Pt. 4, p. 182, pl. 1, fig. 7, January, 1872.

Terebratalia occidentalis Dall, J. P. Smith, Proc. Calif. Acad. Sci., Ser. 4, Vol. 3, pp. 170, 181, 1912. "San Diego-Purisima," Pliocene.—Gale in Grant and Gale, Mem. San Diego Soc. Nat. Hist., Vol. 1, p. 46, 1931 [on pp. 30, 40 as *Terebratalia* (or *Dallinella*) *occidentalis*]. "San Diego formation."—Hertlein and Grant, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 3, p. 127, pl. 10, fig. 3 ("Pacific Beach, San Diego, California, Pliocene"); pl. 17, figs. 2, 5, 8, 11, 12, and text fig. 27 (all Recent), 1944. "Rare in lower 100-200 meters, and in the middle beds of the Pliocene at Pacific Beach, San Diego, California; northeast corner of India and Thorn streets, San Diego, California."

TYPE SPECIMEN: Originally No. 6 in the collection of the California State Survey. A specimen, No. 32180 in the type collection of the University of California, Invertebrate Paleontology, is said possibly to be the type specimen of this species. It is from Loc. 2390, ?Santa Barbara, California, a locality not cited by Dall at the time the species was described.

TYPE LOCALITY: "Habitat, coast of California. Monterey, Cooper and Dall. Catalina Island, Cooper. Cab. Cala. Geol. Survey No. 6."

RANGE: Oligocene to Recent. Recent from Anacapa Island[54], California (Dall), to Cape San Lucas, Lower California, Mexico, in 55 to 137 meters (30 to 75 fathoms).

OCCURRENCE IN THE SAN DIEGO FORMATION: CALIFORNIA ACADEMY OF SCIENCES: Loc. 1399, rare in bluffs 100 to 200 yards south of Eocene-Pliocene contact at Pacific Beach; Loc. 1414, beds in middle portion of Pliocene section at Pacific Beach; Loc. 1419, northeast corner of India and Thorn streets, San Diego; Loc. 12007, Pacific Beach; Loc. 28158, Pacific Beach (L. M. Wright, coll.). LOS ANGELES COUNTY MUSEUM: "Old Town," north of Five Points, San Diego (J. F. Arndt, coll.).

ORIGINAL DESCRIPTION: Shell, variable in size and shade of color, usually of a flesh tint, deeper on some of the lines of growth. Sculptured by radiating ribs variable in number (9 in the typical specimen), with rather smooth interspaces, only crossed by more or less prominent lines of growth. Hinge line long, somewhat arched in the middle; area wide, sharply carinated, flat, crossed by transverse lines of growth. Apex not prominent, usually eroded. Foramen large, incomplete, deltidia widely separated and differentiated from the area by deep grooves. Typical specimen .75 in. long, .6 in. wide and .2 thick. (Dall.)

REMARKS: Most of the specimens of this species that we have seen from Pliocene beds at San Diego are single valves about 28 to 30 mm. in width. They are similar to Recent specimens of *Terebratalia occidentalis*.

The shell of this species varies considerably in sculpture; but it and members of its group are readily distinguished from other west American species of *Terebratalia* by the character of the mesial

(54) This species was recorded as occurring at San Francisco, California, by Cooper and at Monterey by Cooper and Dall. We have not seen specimens of this species from San Francisco. Concerning records of its occurrence at Monterey, California, Smith and Gordon (Proc. Calif. Acad. Sci., Ser. 4, Vol. 26, No. 8, p. 210, 1948) stated, "These are old records that have not been confirmed by recent collecting."

flexure, which is concave on the pedicle valve and convex on the brachial valve. Typical forms of this species are sculptured with about 9 radial ribs, but occasional specimens may have as many as 24 ribs. Some specimens are almost or entirely smooth, the smooth form being the subspecies *obsoleta* Dall[55]. There is complete intergradation between this form and typical *T. occidentalis;* but, although it may not have great taxonomic significance, it can be retained for convenience. Fossil specimens of *T. occidentalis* and its subspecies *obsoleta* attain a width of 45 mm. So far as known, Recent specimens are smaller.

The mesial flexure on specimens of *Terebratalia occidentalis* from the Oligocene and early Miocene is often rather subdued, and since this same tendency is noticeable on early members of *T. transversa* Sowerby, it appears possible that the two groups, *T. occidentalis* and *T. transversa,* may have diverged from a common stock at about this time.

Several related forms belong to the *Terebratalia occidentalis* group. These include *T. occidentalis,* Oligocene to Recent, *T. occidentalis obsoleta* Dall, Miocene to Recent, *T. arnoldi* Hertlein and Grant, early and middle Pliocene, *T. arnoldi quaylei* Hertlein and Grant, late Miocene, *T. arnoldi etchegoini* Hertlein and Grant, late Pliocene, and *T. jordani,* Pliocene (in the Gulf of California region). All these have been discussed and illustrated in our earlier paper, 1944. Woodring[56] and Mattox have questioned the distinctness of *T. arnoldi* from *T. occidentalis,* but an examination of a series of fossil and Recent specimens leads us, at least for the present, to retain *T. arnoldi* as a separate species.

Most of the records of the Recent occurrences of *Terebratalia occidentalis* are from depths not exceeding 91 meters (50 fathoms). According to Mattox it is the second most abundant brachiopod in the waters about Santa Catalina Island, southern California, where it occurs singly or in small clusters, in the ratio of about one to 100 specimens of *Laqueus californianus* Koch.

Genus LAQUEUS Dall

Laqueus Dall, Amer. Jour. Conch., Vol. 6, Pt. 2, p. 123, pl. 7, fig. f; pl. 8, figs. 9, 10, October 6, 1870. "Type. *Laqueus californicus,* Koch sp."—Thomson, New Zealand Board Sci. and Art, Manual No. 7, p. 258, fig. 85 (a, b, c), 1927. "Genotype. *Terebratula californica* Koch."—Hatai, Sci. Repts. Tohoku Imper. Univ., Sendai, Japan, Ser. 2, (Geol.), Vol. 20, p. 343, 1940. "Genotype.—*Terebratula californica* Koch."—Hertlein and Grant, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 3, p. 143, 1944. "Type of the genus (by original designation).—*Laqueus californicus* Koch [=*Terebratula californiana* Koch]."

TYPE SPECIES (by original designation): *Laqueus californicus* Koch [=*Terebratula californiana* Koch].

RANGE: Miocene to Recent, from Japan to Lower California, Mexico. Recent off western North America in from 4 to 252 meters (2 to 138 fathoms), usually in less than 182 meters (100 fathoms). Fragment reported by Dall from a depth of 1575 meters (861 fathoms).

DESCRIPTION: Shell large, ovate, hinge-line curved, biconvex rectimarginate to ligate or strangulate, test smooth, rather coarsely punctate, colour yellow-brown to red, sometimes with bright-red rays. Beak fairly prominent, beak-ridges sharp, foramen small to moderate, permesothyrid, slightly remigrant, telate, deltidial plates conjunct, concave. Hinge-teeth supported by dental plates, which are ventrally recessive; area between dental plates slightly calloused, pedicle-collar (or a striated area) sessile, long, but not reaching as far forward as the dental plates. Cardinalia characterized by inner and outer hinge-plates separated by the crural bases, as in *Dallina,* the inner hinge-plates resting on the median septum; no cardinal process, but a small striated area or pit over the umbo. Septum extending forward more than one-third the length of the valve. Loop long, reflected, attached to the septum by connecting bands as in *Terebratalia,* the ascending branches united to the descending branches by the interconnecting bands on each side in the neighborhood of the connecting bands. Muscular impressions not strong. Small spicules present over the pallial sinuses, but not extending to the body-wall or lophophore. (Thomson, 1927.)

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[55] *Terebratalia occidentalis* var. *obsoleta* Dall, Proc. U.S. Nat. Mus., Vol. 14, No. 849, p. 186, July 24, 1891. "*Albatross,* station 2984, in 113 fathoms, off Cerros Island, Lower California."—Hertlein and Grant, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 3, p. 131, fig. 28, pl. 12, figs. 5, 9-11, 1944 (as *Terebratalia occidentalis obsoleta*). Earlier records cited, Miocene to Recent.

[56] Woodring, W. P., in Woodring, W. P., and Bramlette, M. N., "Geology and Paleontology of the Santa Maria District," U.S. Geol. Surv., Prof. Paper 222, p. 68, 1950.

REMARKS: *Laqueus* is confined to the margins of the north and northeastern Pacific. It is known to occur from Pliocene to Recent in California and from Miocene to Recent in Oregon, Washington, Alaska, and Japan. Species of this genus usually occur at moderate depths on clear sea bottoms free of mud, and a greater number occur in warm rather than cold waters.

Fourteen species were cited by Hatai as occurring in the late Cenozoic of Japan. Two species occur at the present time in waters of the northeastern Pacific region.

KEY TO THE SPECIES OF LAQUEUS

A. Shell thin; pedicle opening small; length usually exceeding 40 mm.....*californianus*

B. Shell thick; pedicle opening large; length usually not exceeding 35-40 mm.....*vancouveriensis diegensis*

Laqueus californianus Koch

Plate 20, Figures 1-3, 5-7

Terebratula californiana Koch in Küster, Martini-Chemnitz Conchyl.—Cab. (ed. by Küster and Kobelt), Bd. 7, Abt. 1, *Terebratula*, p. 38, 1848, pl. 2b, figs. 21-23, 1844.

Laqueus californianus Koch, Hertlein and Grant, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 3, p. 144, pl. 13, figs. 5, 8, 14; pl. 21, figs. 1-7; text fig. 31, 1944. Earlier records cited. ?Pliocene, California. Recent, British Columbia to Point Loma, California.—Mattox, Essays in Nat. Sci. in Honor of Captain Allan Hancock on the Occasion of his Birthday July 26, 1955 (Univ. South. Calif. Press), p. 75, fig. 2, November 8, 1955. Catalina Island, California, in 30 to 120 fathoms, Recent.

TYPE SPECIMEN: Location unknown to the present authors.

TYPE LOCALITY: "Aufenthalt: in Californien."

RANGE: Middle Pliocene, in southern California, to Recent. Recent from British Columbia to Point Loma, California, in 46 to 549 meters (25-300 fathoms); [?] (fragment) 1575 meters (861 fathoms) (Dall.)

OCCURRENCE IN THE SAN DIEGO FORMATION: LOS ANGELES COUNTY MUSEUM: Loc. 107, 100-foot bluff with fossiliferous concretions in clay quarry at end of Arroyo Drive, San Diego.

ORIGINAL DESCRIPTION: T. testa maxima, ovata, ventricoso-convexa, robusta, cornea, opaca, concentrice striata et sulcata, marginibus integris, sinuatis; rostro obtuso, incurvo; area late trigono; foramine integro, parvo.

Muschel sehr gross, eiförmig, bauchig gewölbt, starkwandig und von kräftigem Bau, horngrau, fast glanzlos, mit feinen concentrischen Anwuchsstreifen und stärkeren Furchen, kleiner Schale fast flacher, gegen die Ränder etwas gedrückt, der Oberrand schief, gegen den Wirbel ansteigend, der Wirbel nagelförmig, fast anschliessend. Auf der Fläche beider Schalen zeigen sich mehrere grössere und kleinere Eindrücke, welche sich meist als Furchen bis an den Rand fortsetzen und dort mit denen der andern Schale zusammentreffen. Grössere Schale stärker gestreift, vorzüglich gegen den Unterrand, der Wirbel ist wenig erhöht, stark übergebogen, Schild breit, beiderseits durch eine fast kielförmige Erhöhung abgegränzt; Oeffnung sehr klein, rund. Höhe 27‴, Länge 21‴, Breite 15‴. (Koch.)

REMARKS: Several specimens collected by G. P. Kanakoff at Loc. 107 (LAM), end of Arroyo Drive, San Diego, are referable to *Laqueus californianus*. Some of these are somewhat deformed by compaction of the enclosing sediment, but the observable features are all characteristic of this species: the shell is thin and elongate, with a small pedicle opening. They are uniformly dark brown, probably in part because of iron stain. The largest specimen measures 41.8 mm. in length, 30 mm. in width, and 19.1 mm. in convexity (both valves together). A more rounded specimen measures 38 mm. in length, 33.5 mm. in width, and 18 mm. in convexity (both valves together).

Large specimens of the Recent form attain a length of at least 51.5 mm. Those occurring in shallow water are red, while those in deeper water, from 55 to 110 meters (30 to 60 fathoms), tend to be white. They often occur in colonies, some individuals attached to others. Mattox found one cluster of 31 individuals. Also he found occasional individuals attached to *Bursa californica* Hinds. He reported that in 55 to 219 meters (30 to 120 fathoms) off Catalina Island, *Laqueus californianus* is about 100 times as abundant as *Terebratalia occidentalis* Dall, with which it often occurs.

Records of this species in Pliocene strata are very few. Arnold[57] recorded *"Laqueus californicus (or jeffreysi)"* from Pliocene beds in Temescal Canyon in Los Angeles County, and Thomson (1927, p. 259) recorded it from "Pliocene, California."

Laqueus japonicus Yabe and Hatai[58] bears a resemblance to *L. californianus;* but it is said to differ in the thicker shell, the larger foramen, the more incurved beak, and the brownish coloration.

Under the name *"Laqueus californicus convexus",* Konjukova[58a] recently described a brachiopod with very convex valves and with a very large foramen, from Tatar Strait and the northern part of the Sea of Japan, in 57 to 215 meters. We have not seen specimens.

Laqueus vancouveriensis diegensis Hertlein and Grant, new subspecies

Plate 20, Figures 4, 8-21

Laqueus jeffreysi Dall, Arnold, Mem. Calif. Acad. Sci., Vol. 3, p. 94, 1903. "Pliocene of Pacific Beach."—Arnold, U.S. Geol. Surv., Prof. Paper 47, p. 28, 1906. "San Diego formation as developed in the type section at Pacific Beach."

Not *Laqueus jeffreysi* Dall, 1895.

Laqueus californicus vancouveriensis Davidson, E. K. Jordan and Hertlein, Proc. Calif. Acad. Sci., Ser. 4, Vol. 15, No. 14, pp. 416, 426, pl. 27, fig. 7 (Cedros Island, Pliocene), 1926. "Santa Barbara and San Diego Pliocene formations of southern California."—Hertlein, Stanford Univ. Bull., Ser. 5, No. 78, p. 82, 1929. "San Diego Pliocene."

Not *Laqueus californicus* var. *vancouveriensis* Davidson, 1887.

Laqueus vancouveriensis Davidson, Hertlein and Grant, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 3, p. 147, pl. 13, figs. 6, 7, 9, 10, 1944. "Pacific Beach, San Diego, California. Pliocene." (Not pl. 17, figs. 15-17; pl. 18, figs. 15-17, 19-21; text fig. 32 =*L. vancouveriensis* Davidson).

Not *Laqueus californicus* var. *vancouveriensis* Davidson, 1887.

TYPE SPECIMEN: No. 7355 (and Paratype No. 7354), Type Collection, Department of Geology, California Academy of Sciences. Paratypes, San Diego Society of Natural History and Los Angeles County Museum.

TYPE LOCALITY: Pacific Beach, San Diego, California; Pliocene; H. Hemphill, collector. Paratypes also from Pacific Beach.

RANGE: Middle Pliocene in southern California and at Cedros Island, Lower California, Mexico.

OCCURRENCE IN THE SAN DIEGO FORMATION: San Diego (Arnold; E. K. Jordan and Hertlein; Hertlein; Hertlein and Grant). CALIFORNIA ACADEMY OF SCIENCES: Locs. 104, 537, 12005, 12006, 31356, Pacific Beach; Loc. 28884, embankment on Windsor Drive where Tourmaline Street would intersect if projected. LOS ANGELES COUNTY MUSEUM: Loc. 122, 20 to 30 feet below end of Loring Street, Pacific Beach; Loc. 308, 0.2 mile north of intersection of Harbor Boulevard and Tourmaline Street, Pacific Beach; Loc. 311 [=Loc. 28884 (CAS)]; Loc. 311A, at base of recent road cut on Windsor Drive about 20 feet toward embankment from Loc. 311 (LAM); Loc. S8439, north end of Diamond Street (Charles Sternberg, Coll.). SAN DIEGO SOCIETY OF NATURAL HISTORY: Loc. 81, south slope of Soledad Mountain; Loc. 726, Pacific Beach; Loc. 5007 [=Loc. 28884 (CAS)]. UNIVERSITY OF CALIFORNIA AT LOS ANGELES: Loc. 593 [=Loc. 28884 (CAS) and Loc. 726 (SD)]; Loc. 2420, soft yellow Pliocene sands exposed in bluffs along Pacific Beach about ½ mile southeast of False Point at foot of Law Street.

DESCRIPTION: Shell with general characters of *Laqueus vancouveriensis* Davidson but differing in that the umbo of the pedicle valve is broader and has a larger pedicle opening, the posterior margin of the brachial valve is more broadly rounded, and the shell is larger and thicker. Dimensions: length 34.5 mm.; width 29.5 mm.; convexity (both valves together) 21.6 mm.

REMARKS: This form has been recorded from Pliocene beds in Lower California and in southern California[59], at least in some instances under the name of *Laqueus vancouveriensis* Davidson. That species now occurs from the Aleutian Islands, Alaska, to off Lopez Island, Puget Sound, Washington. Comparison of many fossil specimens from San Diego with Recent specimens shows differences which appear sufficient to justify the separation of the fossils as a subspecies.

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[57] Arnold, R., "The Tertiary and Quaternary Pectens of California," U.S. Geol. Surv., Prof. Paper 47, p. 77, 1906. See also U.S. Geol. Surv., Bull. 309, p. 153, 1907 (as *Laqueus californicus*? Koch).

[58] *Laqueus japonicus* Yabe and Hatai, Proc. Imper. Acad. Japan, Vol. 10, No. 10, p. 663, figs. 19-21, 26, December, 1934. "Type loc.: Sagami Bay?."—Hatai, Sci. Repts. Tohoku Imper. Univ., Sendai, Japan, Ser. 2 (Geol.), Vol. 20, p. 365, pl. 5, figs. 10-19, 23-25, 1940. Miocene or Pliocene to Recent, Japan.

[58a] Konjukova, E.D., Akad. nauk SSSR, Zool Inst., Issledovaniia Dal'nevostochnikh Morei SSSR (Moskva; Leningrad), Vol. 4, p. 53, figs. 37, 38, pl. 7, figs. 1-12, 1957.

[59] George Willett (Bull. South. Calif. Acad. Sci., Vol. 45, Pt. 1, January-April, p. 32, June 10, 1946) mentioned the occurrence of *Laqueus "vancouverensis"* Davidson in strata of Pliocene age at Fourth and Broadway streets in Los Angeles, California.

This fossil form differs from the species described by Davidson[60] in the gross shell characters mentioned above. The shell is decidedly thicker and attains a larger size. Dimensions of five of the largest specimens are as follows:

	Length	Width	Convexity
Holotype (CAS) from Pacific Beach	34.5 mm.	29.5 mm.	21.6 mm.
Paratype (CAS) from Pacific Beach	33.8 mm.	31.0 mm.	20.5 mm.
Paratype (SD) from Pacific Beach	30.6 mm.	24.0 mm.	20.8 mm.
Paratype (LAM) from Pacific Beach	36.4 mm.	28.0 mm.	23.0 mm.
Hypotype (CAS) from Cedros Island	37.9 mm.	33.8 mm.	23.0 mm.

The largest Recent specimen of *Laqueus vancouveriensis* which has come to our attention is 34.5 mm. in length. This is unusual: the average length is about 25.3 mm.

Both *Laqueus vancouveriensis* and the new subspecies described here differ from *Laqueus californianus* Koch in the smaller size, thicker shell, and larger pedicle opening. Recent specimens of *L. vancouveriensis* are drab or yellowish rather than pink or white as in *L. californianus*; and they usually occur singly or in small groups rather than in huge colonies.

This new subspecies occurs rather abundantly in the Pacific Beach district at Loc. 28884 (CAS), in the embankment on Windsor Drive where Tourmaline Street would intersect if projected, and at Loc. 308 (LAM), 0.2 mile north of the intersection of Harbor Boulevard and Tourmaline Street.

[60] *Laqueus californicus* var. *vancouveriensis* Davidson, Trans. Linn. Soc. London, Ser. 2, Zool., Vol. 4, Pt. 2, p. 113, pl. 18, figs. 10-13, 13a, 13b, July, 1887. "Off Vancouver Island." Also other localities cited. See Hertlein and Grant, 1944, p. 147, pl. 17, figs. 15-17; pl. 18, figs. 15-17, 19-21; text fig. 32.

Dr. Helen M. Muir-Wood informed us that syntypes of this form in the Department of Paleontology, British Museum (Natural History), illustrated by Davidson, bear the following numbers: plate 18, fig. 10 = ZB. 1611; fig. 11 = ZB. 1610; fig. 12 = ZB.1 2459; fig. 13 = ZB. 1609.

Phylum **ECHINODERMATA** Bruguière

Class **ASTEROIDEA** Burmeister

Order **PHANEROZONIA** Sladen

Family **ASTROPECTINIDAE** Gray

Back flattish, netted with numerous tubercles, crowned with radiating spines at the tip, called Paxilli. (Gray, 1840). Jurassic to Recent.

Genus **ASTROPECTEN** Linck in Gray

Astropecten Linck in Gray, Ann. and Mag. Nat. Hist., Vol. 6, No. 36, p. 180, November, 1840. Several species cited including "*Astropecten aurantiacus*. Asterias aurantiaca, *Linn.*"—Fisher, Smithson. Miscell. Coll., Vol. 52, No. 1799, p. 93, May 27, 1908. Type: *Astropecten aurantiacus* Linnaeus.—Fisher, U. S. Nat. Mus., Bull. 76, Pt. 1, p. 55, June 30, 1911. Type as indicated in 1908.

TYPE SPECIES (designated by Fisher, 1908, p. 93): "No type was designated by Gray; as it is desirable to have one, *A. aurantiacus*[61] (Linn.) may be so considered." [= *Asterias aranciaca* Linnaeus, Syst. Nat., ed. 10, p. 662, 1758. "Habitat in M. Mediterraneo." Ref. to "Link. Stell. t.4.f.14; t.5.f.6; t.8.f.12; t.23.f.38; t.27.f.44; t.36.f.63"; also others. Also illustrated by Ludwig, Fauna und Flora des Golfes von Neapel (Berlin), Monogr. 24, pp. 3-16, pl. 2, figs. 1, 2,; pl. 6, figs. 1-5; text fig. on p. 3, 1897 (as *Astropecten aurantiacus*). Mediterranean; Madeira; Bay of Setubal, Portugal; Canary Islands. Depth, 1-183 meters. — H. L. Clark in Eastman's ed. 2 of Zittel's Text-Book of Paleo., Vol. 1, p. 247, fig. 349, 1913. Recent, Mediterranean].

RANGE: Miocene to Recent (Hess). Cosmopolitan. Species assigned to this genus by Sladen, 1889, occur at depths of 4 to 823 meters (2 to 450 fathoms), but most of them occur at depths less than 91 meters (50 fathoms).

DESCRIPTION: Rays normally five in number; abactinal surface flat, not arched; actinal surface slightly beveled on sides; disk variable in size, usually medium to small; rays usually long and tapered; marginal plates large, the inferomarginals always broader than superomarginals and sometimes extending laterally beyond them; inferomarginals armed with spinelets and a variable number of spines which increase in size toward the edge of ray; superomarginals, in addition to small granules or spinelets, may also bear tubercles or enlarged spines extending in one or two complete or interrupted rows along ray; or enlarged spines may be entirely absent; exposed surface of consecutive marginal plates separated by deep fasciolar grooves lined by minute capillary spinelets, these grooves acting as percolators or filters; abactinal area covered with true paxillae; papulae single, usually absent from a narower or wider midradial line, and from center of disk; usually six about each paxilla; actinal interradial areas typically very small, with few paxilliform intermediate plates which do not extend far along ray, the inferomarginals and adambulacrals being in contact on the ray proper; intermediate plates never extend beyond middle of ray and rarely beyond proximal fourth; ambulacral plates with an angular furrow margin, bearing typically three spines, of which the middle is slightly the longer; two or three rows of spines on actinal surface of plates; first adambulacral plate compressed, much wider than the rest; mouth plates narrow, the inner spines enlarged; tube feet conical, without a true sucking disk; no true pedicillariae; anus typically absent; gonads interradial, not extending along ray; superambulacral plates well developed. (Fisher, 1911.)

REMARKS: *Astropecten* differs from *Tritonaster* Fisher in the character of the superomarginal plates, which are not conspicuously smaller beyond the middle of the ray, and in the presence of well-developed marginal fascioles.

Fisher (1908) discussed the problems concerning the nomenclature of this genus. He pointed out that *Astropecten* of Linck, 1733, is pre-Linnaean, that *Astropecten* of Schultz, 1760, is non-binomial,

(61) The specific name *aranciaca* Linnaeus was emended to *aurantiaca* by Tiedemann, 1816. See H. L. Clark, Carnegie Inst. Washington, Publ. 566, p. 72, 1946.

and hence that neither is available. He did not mention the usage of the genus name by Blainville[62], who accepted Linck's genus. For the present we accept Gray's usage of the genus name and leave any further nomenclatural questions concerning it to specialists in the Asteroidea.

Durham and Roberts[63] summarized the known occurrences of fossil asteroids in North America. They described *Astropecten matilijaensis* from beds of late Cretaceous age in Ventura County, California; but this species appears to belong in *Archastropecten,* where it was placed by Hess (1955, p. 44). Therefore, *Astropecten armatus,* from Pliocene beds in San Diego, is the only known fossil *Astropecten* in western North America.

Hess[64] reviewing the species of fossil Astropectinidae, transferred most of the previously described Mesozoic fossils from *Astropecten* to *Archastropecten* Hess. The type of this genus is *Astropecten huxleyi* Wright, 1862, from strata of late Jurassic age in England. According to Hess, the most important distinction between the two genera is the character of the flattened surfaces of the joints of the marginal plates. In *Archastropecten* these surfaces are large and simple and differ proximally and distally; consequently, they fit together very closely. In *Astropecten* these surfaces are smaller, more deeply excavated, and more differentiated.

Asterias rémondii Gabb[65] was described long ago from beds now referred to the San Pablo formation of late Miocene age in the San Francisco Bay district in California.

Astropecten armatus Gray

Plate 23, Figures 8, 9

Astropecten armatus Gray, Ann. and Mag. Nat. Hist., Vol. 6, No. 36, p. 181, November, 1840.—Fisher, U. S. Nat. Mus., Bull. 76, Pt. 1, p. 56, pl. 5, figs. 1-2; pl. 7, figs. 3,6; pl. 50, fig. 4; pl. 51, fig. 3, June 30, 1911. San Pedro, California, to Punta Santa Elena, Ecuador, Recent.—Ziesenhenne, Zoologica, New York Zool. Soc., Vol. 22, Pt. 3, p. 211, October 7, 1937. San Pedro, California, to Punta Santa Elena, Ecuador; Clarion Island; Recent.

TYPE SPECIMEN: No. 1938.5.12.27., British Museum (Natural History).

TYPE LOCALITY: "Inhab. Puerto Portrero, South America, on sandy bottoms, 9 fathoms. H. Cuming, Esq. Var. 2." [Costa Rica.]

RANGE: Middle Pliocene to Recent. Recent from San Pedro, California, to Punta Santa Elena, Ecuador; Clarion Island, Revillagigedo Islands, Mexico. Shore to 146 meters (80 fathoms), on muddy, sandy, and rocky bottoms. (Ziesenhenne.)

OCCURRENCE IN THE SAN DIEGO FORMATION: UNIVERSITY OF CALIFORNIA AT LOS ANGELES: Corner of Market Street and Euclid Avenue, San Diego.

ORIGINAL DESCRIPTION: Rays elongate, regularly tapering; upper marginal tubercles narrow, with a continued series of erect, elongated, subulate spines. Var. 2. *Pulcher,* the under series of marginal tubercles not produced, and the spines more slender. (Gray).

Diagnostic features of this species given by Fisher (1911, p. 60) follow:

"*Armatus* may be distinguished from the other two Californian astropectens by the presence of at least a few superomarginal spines or tubercles, by the broader and more tumid superomarginal plates, by the enlarged central granules of the paxillae, by the heavier and more bristling inferomarginal armature, and especially by the chisel-shaped enlarged adambulacral spine, which is broader at tip than at base, and usually more or less hollowed at the end, on the upper (or outer) side, like a gouge. Even young specimens of *armatus* have a few superomarginal tubercles, although these are usually inconspicuous. In lieu of the superomarginal spines the enlarged central granules of paxillae and the specialized adambulacral spine may be used to determine doubtful specimens." (Fisher, 1911.)

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(62) Blainville (Dict. Sci. Nat., Vol. 60, p. 220, 1830) cited "(*G. Astropecten*, Link; *Crenaster*, Luid.)", with 30 species, of which *A. aranciaca* is the first one.

(63) Durham, J. W., and Roberts, W. A., "Cretaceous Asteroids from California," Jour. Paleo., Vol. 22, No. 4, pp. 432-439, pls. 65, 66, July, 1948. Two new species were described by Durham and Roberts. These are *Astropecten matilijaensis* (p. 435, pl. 65, figs. 1-5; pl. 66, figs. 2, 4, 5) and *Henricia*(?) *venturana* (p. 437, pl. 66, figs. 1, 3), from "6.3 miles northeast along the road from Wheeler Springs, on the highway from Ojai to the Cuyama Valley. Referring to the 1942 reprint of the 1903 edition of the Mt. Pinos, Calif. Quadrangle . . . the locality appears to be in the SE¼ of the SE¼ of Sec. 2, T5N, R23W, Ventura County, California."

(64) Hess, H., "Die Fossilen Astropectiniden (Asteroidea). Neue Beobachtungen und Übersicht über die bekannten Arten," Schweiz. Palaeo. Abhandl., Bd. 71, No. 3, pp. 1-113, figs. 1-62, pls. 1-4, 1955.

(65) *Asterias rémondii* Gabb, Geol. Surv. Calif., Palaeo., Vol. 2, p. 37, pl. 13, fig. 69, February, 1866. "Found abundantly at 'Star Fish Point,' on the Pinole Ranch, south of the Straits of Carquinez, about five miles from Martiñez; Miocene."

REMARKS: A portion of a single ray, 13.8 mm. in length and 12 mm. in maximum width, with 8 plates in one series and 6 in the other, is in the collection of the University of California at Los Angeles. It was collected by B. H. Brattstrom at the corner of Market Street and Euclid Avenue, San Diego. This fragment is similar in observable characters to the corresponding portion of *Astropecten armatus* Gray, which at the present time occurs in the waters off San Diego. This conclusion was affirmed by Mr. Fred C. Ziesenhenne, who compared the fossil with a series of Recent specimens of *A. armatus* in the Allan Hancock Foundation. The fossil is therefore referred to the Recent species.

Class ECHINOIDEA Leske

A paper by the present authors published in 1938[66] contains many references to and discussions of west American Cenozoic Echinoidea. Since the submission of our monograph on west American Cenozoic Echinoidea, several important papers have appeared, including those of Ziesenhenne[67], A. H. Clark[68], H. L. Clark[69], Caso[70], and Durham[71], as well as the later portions of the great monograph by Mortensen[72].

Mayr[73] published an interesting paper dealing with speciation in tropical American echinoids. C. W. Cooke[74] is the author of two very useful papers dealing with the Cenozoic echinoids of the eastern United States. A recent paper by Durham and Melville[75] deals with the classification of echinoids.

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(66) Grant, U. S., IV, and Hertlein, L. G., "The West American Cenozoic Echinoidea," Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 2, pp. i-vi, 1-225, figs. 1-17, pls. 1-30, April 19, 1938.

(67) Ziesenhenne, F. C., "The Templeton Crocker Expedition. X. Echinoderms from the West Coast of Lower California, the Gulf of California and Clarion Island," Zoologica, New York Zool. Soc., Vol. 22, Pt. 3, pp. 209-239, figs. 1, 2, October 7, 1937.

(68) Clark, A. H., "Echinoderms from the Pearl Islands, Bay of Panamá, with a Revision of the Pacific Species of the Genus Encope," Smithson. Miscell. Coll., Vol. 106, No. 5, (Publ. 3849), pp. 1-11, pls. 1-4, July 18, 1946.

(69) Clark, H. L., "A Report on the Echini of the Warmer Eastern Pacific, Based on the Collections of the Velero III," Allan Hancock Pac. Exped., Vol. 8, No. 5, pp. 225-352, figs. 1-3, pls. 35-71, December 29, 1948. ("Hubert Lyman Clark: Teacher and Friend", by F. A. Chase, Jr., pp. ii-iv and portrait; "Bibliography of Dr. H. L. Clark's Echinoderm Papers," by Marjorie Pattee, pp. v-ix; "Preface", by Th. Mortensen, pp. xi-xii).

(70) Caso, M. E., "Contribucion al Conocimiento de los Equinoideos de Mexico," An. Inst. Biol. Mexico, Vol. 17, Nos. 1 & 2, pp. 247-259, figs. 1-10, 1946; also Vol. 19, No. 1, pp. 183-231, figs. 1-24, 1948; Vol. 20, Nos. 1 & 2, pp. 342-355, figs. 1-6, 1949. See also: "Los Equinoides Fósiles del Cenozoico de México," Bol. Assoc. Mex. Geol. Petrol., Vol. 3, Nos. 1-2, pp. 37-96, 1951; "El Genero Clypeaster Lamarck 1801, en el Terciario de Mexico," An. Inst. Biol. Univ. Mexico, Tom. 27, No. 2, pp. 487-528, figs. 1-23, 1 table, 1957.

(71) Durham, J. W., "Classification of Clypeasteroid Echinoids," Univ. Calif. Publ. Geol. Sci., Vol. 31, No. 4, pp. i-v, 73-198, figs. 1-38, frontispiece and pls. 3-4, November 21, 1955.

(72) Mortensen, Th., "A Monograph of the Echinoidea."

I. Cidaroidea, text (pp. 1-551, 173 figs.), atlas (pp. 1-24, pls. 1-88), December 7, 1928.

II. Bothriocidaroida, Melonechinoida, Lepidocentroida, and Stirodonta, text (pp. 1-647, 377 figs.), atlas (pp. 1-16, pls. 1-89), February 22, 1935.

III.1. Aulodonta, text (pp. 1-370, 197 figs.), atlas (pp. 1-22, pls. 1-77), April 25, 1940.

III.2. Camarodonta. I, text (pp. 1-553, 321 figs.), atlas (pp. 1-23, pls. 1-56), February 22, 1943.

III.3. Camarodonta. II, text (pp. 1-446, 215 figs.), atlas (pp. 1-23, pls. 1-66), October 1, 1943.

IV.1. Holectypoida and Cassiduloida, pp. 1-371, pls. 1-14, 326 figs. in text, February 7, 1948.

IV.2. Clypeastroida, text (pp. 1-471, 258 figs.), atlas (pp. 1-20, pls. 1-72), December 30, 1948.

V.1. Spatangoida. I, pp. 1-432, pls. 1-25, 315 figs. in text, December 21, 1950.

V.2. Spatangoida. II, text (pp. 1-593, 286 figs.), atlas (pp. 1-30, pls. 1-64), December 20, 1951.

Index to Vols. I-V, pp. 1-62. Additional note, p. 63, December 20, 1951.

(73) Mayr, E., "Geographic Speciation in Tropical Echinoids," Evolution, Vol. 8, No. 1, pp. 1-18, figs. 1-7 (maps), March 31, 1954.

(74) Cooke, C. W., "Cenozoic Regular Echinoids of Eastern United States," Jour. Paleo., Vol. 15, No. 1, pp. 1-20, pls. 1-4, January, 1941; "Cenozoic Irregular Echinoids of Eastern United States," Jour. Paleo., Vol. 16, No. 1, pp. 1-62, pls. 1-8, January, 1942.

While the present paper was in press, there appeared another publication of C. W. Cooke: "Cenozoic Echinoids of Eastern United States", U. S. Geol. Surv., Prof. Paper 321, pp. i-iii, 1-106, pls. 1-43, 1959.

(75) Durham, J. W., and Melville, R. V., "A Classification of Echinoids," Jour. Paleo., Vol. 31, No. 1, pp. 242-272, figs. 1-9, January, 1957.

Order CIDAROIDA Claus

Family CIDARIDAE Gray

Test stout, with relatively few plates in each interambulacral column; each plate with one primary spine or none. Primary spines very large. Primary tubercles perforate. (H. L. Clark, 1925.) Jurassic to Recent.

KEY[76] TO THE GENERA OF CIDARIDAE

A. Primary spines coarse, ending in a small crown with a central prominence (more rarely tapering to a fine point); pores on peristome partly in double series (not in *E. metularia*) ..... *Eucidaris*

B. Primary spines slender, sometimes widened and flattened towards the end; pores on peristome in single series ..... *Hesperocidaris*

Genus EUCIDARIS Pomel

Eucidaris Pomel, Méth. et. Gén. Echin. Viv. Foss. [Paléo. Descript. Anim. Foss. de L'Algérie, Zooph. (Alger), Fasc. 2], p. 109, 1883.—Mortensen, Monogr. Echin. I. Cidaroidea, p. 384, 1928. "Genotype: *Cidarites metularia* Lamarck."—Grant and Hertlein, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 2, p. 7, 1938. "Type of the genus (designated by H. L. Clark, ... 1909): *Cidaris metularia* Lamarck."

TYPE SPECIES (designated by H. L. Clark, Ann. and Mag. Nat. Hist., Ser. 8, Vol. 3, p. 88, January, 1909): *Cidaris metularia* Lamarck [= *Cidarites metularia* Lamarck, Anim. s. Vert., Vol. 3, p. 56, 1816. "Habitate l'océan des Grandes-Indes, les Côtes de l'Ile-de-France, celles de Saint-Domingue." Illustrated by A. Agassiz, Illustr. Cat. Mus. Comp. Zool., No. 7 (Mem. Mus. Comp. Zool., Vol. 3), pt. 1, p. 98, 1872; Pt. 3, p. 385, pl. 1c, figs. 23, 23a, 23b, 24, 24a, 24b; pl. 1g, fig. 1; pl. 35, fig. 3, 1873 (as *Cidaris metularia*). "Red Sea; Mauritius; East India Islands; Sandwich Islands; Feejee Islands."—Mortensen, Monogr. Echin. I. Cidaroidea, p. 386, pl. 41, figs. 1-8; pl. 73, fig. 6; pl. 86, figs. 11-14, text figs. 113a, 113b, 114, 115 (1), 116, 1928. All over Indo Pacific.]

RANGE: Miocene to Recent in West Indies, Panama, and North America. Also Recent on the west coast of Africa and in the Indopacific region. Bathymetric range, from littoral zone to 570 meters (311 fathoms).

ORIGINAL DESCRIPTION: *Eucidaris.* Tubercles à col lisse; trois espèces vivantes; presque toutes les espèces tertiaries; toutes les espèces crétacées moins une (20); quelques jurassiques seulement (*C. Moieri Honorinae, propinqua, marginata, monilifera, multipunctata*); la plupart des triasiques (7). (Pomel.)

SUPPLEMENTARY DESCRIPTION: Pores not conjugate, wall rising into a rounded prominence; pores on peristome in larger specimens more or less distinctly biseriate (not in *metularia*). Madreporite slightly enlarged. Primary spines typically cylindric, terminating in a small crown with a central prominence; the shaft with low, rounded warts arranged in rather distinct longitudinal series. General surface of shaft usually covered with a thick, spongy coat of anastomosing hairs. Sometimes the primaries may be fusiform, tapering to a simple point, sometimes they are very thick, clubshaped. Secondary spines rather appressed. Large globiferous pedicellariae without an end tooth, with or without a limb on the stalk. Small globiferous pedicellariae with a small, but distinct end tooth. Tridentate pedicellariae may occur in two distinct forms, both with long, slender valves. (Mortensen, 1928.)

REMARKS: Pomel mentioned "trois espèces vivantes" in his original description of this genus. Döderlein, 1887, used the genus *Eucidaris* in a modern sense and mentioned *E. metularia* as the first species. This species was considered to be the type of the genus by H. L. Clark, 1909, by Mortensen, and by others. Bather (Ann. and Mag. Nat. Hist., Ser. 8, Vol. 3, p. 88, 1909) stated, "We may well suppose that the 'trois espèces vivantes' of Pomel's list were *Cidaris metularia, C. tribuloides,* and *C. thouarsi.*"

This procedure is not in strict conformity with the International Rules of Zoological Nomenclature. However, in view of the fact that nearly all workers on Echinoidea accept *Cidarites metularia* Lamarck as the type of the genus *Eucidaris,* we continue this practice.

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[76] Adapted from Mortensen, 1928, p. 321.

Five living species and subspecies of *Eucidaris* were recognized by Mortensen. Two of these occur in the warmer waters of western North America.

Eucidaris cf. **E. thouarsii** Valenciennes

Plate 24, Figures 19-22

The following are references to typical *E. thouarsii.*

Cidaris thouarsii Valenciennes in L. Agassiz and Desor, Ann. Sci. Nat. (Zool), Ser. 3, Vol. 6, p. 326 [typ. err. 324], 1846.

Eucidaris thouarsii Valenciennes, Mortensen, Monogr. Echin. I. Cidaroidea, p. 393, pl. 42, figs. 5-12; pl. 57, figs. 1 and 2; pl. 73, figs. 3-5; pl. 86, figs. 1-7; text figs. 115 (2), 117, 118 (1, 3), 1928. Lower California to Panama and the Galapagos Islands, shore to 45 meters.—Grant and Hertlein, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 2, p. 7, pl. 2, figs. 1, 2, 1938. Earlier records cited. ?Miocene, Pliocene to Recent.—H. L. Clark, Allan Hancock Pac. Exped., Vol. 8, No. 5, p. 229, pl. 35, fig. 1, 1948. Gulf of California to La Plata Island, Ecuador. Also the islands off the coast.

TYPE SPECIMEN: Muséum National d'Histoire Naturelle de Paris[77].

TYPE LOCALITY: "Californie. (Neboux.) Gallopagos."

RANGE: ?Middle Miocene in California and Lower California, and ?late Miocene, (Túxpan formation, Vera Cruz), eastern Mexico. Pliocene to Recent. Recent, common in the western Americas from San Felipe Bay near the north end of the Gulf of California to La Plata Island, Ecuador; also Guadalupe Island[78] (C. Limbaugh, coll.), Alijos Rocks and Revillagigedo Islands, Mexico, Cocos Island and Galapagos Islands, from shore to 139 meters (76 fathoms).

OCCURRENCE IN THE SAN DIEGO FORMATION: CALIFORNIA ACADEMY OF SCIENCES: Loc. 12163, Pacific Beach, (spines). LOS ANGELES COUNTY MUSEUM: Loc. 122, 20 to 30 feet below end of Loring Street, Pacific Beach, (spines); Loc. 305, 2400 feet east and 1350 feet south of the northwest corner of Sec. 8, T.19S., R.2W., San Bernardino Base and Meridian (see U.S. Geol. Surv. topographic map, San Ysidro quadrangle, ed. 1943), (spines); Loc. 308, 0.2 mile north of intersection of Harbor Boulevard and Tourmaline Street, Pacific Beach, (spines).

ORIGINAL DESCRIPTION: Aires ambulacraires étroites, composées de quatre rangées de granules, dont les deux internes sont à peine développées. Base des tubercles large. Espace granuleux intermédiaire entre les rangées, étroit. Granules assez apparents, peu serrés. Piquants subcylindriques, enflés, très granuleux, rappelant ceux du *C. Blumenbachii.* (Valenciennes.)

REMARKS: The fossils recorded here from the San Diego formation are spines. Many were collected by G. P. Kanakoff at Loc. 305 (LAM), near the Mexican boundary. One of the largest spines measures 5 mm. in diameter. Similar spines were collected by Kanakoff at Loc. 308 (LAM), 0.2 mile north of the intersection of Harbor Boulevard and Tourmaline Street, and at Loc. 122 (LAM), Pacific Beach. Spines collected by Henry Hemphill from Pliocene strata at Pacific Beach are in the collections of the California Academy of Sciences.

These spines have been compared with those of a series of Recent specimens of *Eucidaris thouarsii* in the collections of the California Academy of Sciences. Mr. Fred C. Ziesenhenne likewise compared these specimens with Recent ones in the collections of the Allan Hancock Foundation, and he could detect no essential differences other than those due to weathering. Only spines of the fossil form are known from the Pliocene beds at San Diego; therefore, we adopt the conservative course and record only a provisional identification of the species.

The collections of the Los Angeles Museum include a single incomplete but moderately well preserved plate of a cidarid from Loc. 305 (LAM). Comparing this with plates of Recent species of Cidaridae, Mr. Ziesenhenne concluded that it resembles plates of *Cidaris, Histocidaris,* and even *Stereocidaris,* more closely than it resembles *Eucidaris.*

Specimens apparently referable to *E. thouarsii* occur in beds of Pliocene age in the Galapagos Islands and in Imperial County, California, and in beds of late Pliocene and Pleistocene age in the Gulf of California.

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[77] Dr. André Franc, Muséum National d'Histoire Naturelle de Paris, informed us (written communication) that Mr. G. Cherbonnier in that institution made a search for the type specimen of *Cidaris thouarsii* Valenciennes. Mr. Cherbonnier's opinion is that the type may be one of two specimens in the museum which were collected by M. Neboux, but he cannot determine with certainty whether either of these unnumbered and poorly preserved specimens is the type.

[78] Recent discovery of the occurrence of this species at Guadalupe Island and at Alijos Rocks by members of an expedition of the Scripps Institution of Oceanography was called to our attention by Edwin C. Allison.

Many years ago a spine from the Monterey formation of late Miocene age in San Mateo County, California, was submitted by Ralph Arnold to H. L. Clark for identification. The latter stated[79], "I do not think it shows a single feature by which it can be distinguished from *thouarsii*. If it is not *thouarsii*, it is certainly from the ancestor of that species." *Eucidaris thouarsii* was cited by Jackson[80] as occurring in the Miocene Túxpan formation, Vera Cruz, Mexico. Toula[81] mentioned that a species occurring in the Gatun formation of middle or late Miocene age in Panama shows a relationship with *Eucidaris tribuloides* Lamarck and with *E. thouarsii*.

Loel and Corey[82] cited "*Cidaris thouarsii*(?) Valenciennes (Kew)" from beds of middle Miocene age in the Santa Ana and Santa Monica mountains. We have not studied specimens from those areas.

Eucidaris thouarsii galapagensis Döderlein from the Galapagos Islands has thick club-shaped spines with the collar of the primaries somewhat longer than that of typical *thouarsii*. H. L. Clark did not consider this form worthy of recognition, but Mortensen (1928, p. 399, pl. 42, fig. 13; pl. 86, figs. 8-10) believed it to be at least a valid variety and perhaps a distinct species. Both *E. thouarsii* and the form *galapagensis* occur at the Galapagos Islands.

Genus **HESPEROCIDARIS** Mortensen

Hesperocidaris Mortensen, Vid. Medd. Dansk. Nat. For. København, Bd. 85, p. 73, 1928. "Genotype: *Dorocidaris panamensis* A. Agassiz."—Mortensen, Monogr. Echin. I. Cidaroidea, p. 415, 1928. "Genotype: '*Dorocidaris*' *panamensis* A. Agassiz." —Grant and Hertlein, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 2, p. 9, 1938. "Type (by original designation): *Dorocidaris panamensis* A. Agassiz."

TYPE SPECIES (by original designation): *Dorocidaris panamensis* A. Agassiz[83] [Bull. Mus. Comp. Zool., Vol. 32, No. 5, p. 73, pl. 1; pl. 2, fig. 1, 1898. Off Cocos Island, in 66 and in 100 fathoms. Off Galera Point, in 85 and in 112 fathoms. Also illustrated by A. Agassiz, Mem. Mus. Comp. Zool., Vol. 31, pp. 20-23, pls. 1-4; text figs. 3, 12, 22-24, 26-29, 43-45, 1904. Original locality cited. Bathymetric range, 66-112 fathoms. —Mortensen, 1928, pp. 416-419, pl. 18, fig. 8; pl. 73, fig. 8; pl. 82, figs. 23-29; text figs. 124-127, 1928. —H. L. Clark, Allan Hancock Pac. Exped., Vol. 8, No. 5, p. 230, pl. 35, fig. 2, 1948.]

RANGE: Paleocene to Recent, western America. Recent from the Gulf of California to Galera Point, Ecuador; also Clarion Island, Cocos Island, and Galapagos Islands; in from 55 to 274 meters (30 to 150 fathoms).

DESCRIPTION: Pores not conjugate, wall nearly flat; pores on peristome in single series. Madreporite not enlarged. Primary spines slender, with low granules arranged in longitudinal series; cylindrical, not tapering, but sometimes conspicuously widened and flattened towards the end, the surface covered with a thick, spongy coat of anastomosing hairs. Secondary spines not strongly appressed. Large globiferous pedicellariae without an end tooth and without a limb on the stalk. Small globiferous with a small end tooth. Tridentate pedicellariae of one form only, with slender valves. (Mortensen, 1928, p. 415.)

REMARKS: *Hesperocidaris* resembles *Stylocidaris* (see Mortensen, 1928, p. 334; type, *Cidaris affinis* Philippi) in general characters. The two genera differ, however, in the character of the primary spines. Those of *Stylocidaris* usually taper to a fine point, the hairs on the surface of the shaft are usually simple, sometimes lacking, and the large globiferous pedicellariae possess a well developed limb on the stalk. *Stylocidaris* is essentially an Indo-Pacific genus represented in those waters by about 16 species. Two species occur in the Caribbean and one of them also in the mid-Atlantic and Mediterranean.

So far as known, fossil and Recent species of *Hesperocidaris* occur only in the western Americas.

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(79) Clark, H. L., in Arnold, R., Proc. U. S. Nat. Mus., Vol. 34, No. 1617, p. 359, August 8, 1908.

(80) Jackson, R. T., Proc. U. S. Nat. Mus., Vol. 84, No. 3015, p. 229, 1937.

(81) *Cidaris* sp., Toula, Jahrb. Kais.-Kgl. Geol. Reichsanst., Bd. 58, Heft 4, p. 735, 1909.

(82) Loel, W., and Corey, W. H., "The Vaqueros Formation, Lower Miocene of California. I. Paleontology," Univ. Calif. Publ. Bull. Dept. Geol. Sci., Vol. 22, No. 3, p. 167, December 31, 1932. Also p. 141.

(83) Fred C. Ziesenhenne (verbal communication) pointed out to us that *Stylocidaris houstonia* A. H. Clark (Smithson. Miscell. Coll., Vol. 98, No. 11 (Publ. 3536), p. 12, pl. 4, figs. 10, 11; pl. 5, figs. 12-14, June 2, 1939, "Galápagos Islands: Tagus Cove, Albemarle Island; from the anchor chain in 50 fathoms (91 m.) of water.") is identical with *Hesperocidaris panamensis* A. Agassiz.

Hesperocidaris perplexa H. L. Clark

Plate 24, Figures 6, 7, 9, 10, 12, 14

Tretocidaris perplexa H. L. Clark, Bull. Mus. Comp. Zool., Vol. 51, No. 7, p. 205, pl. 6, figs. 1, 2; pl. 7, figs. 1-4, December, 1907.

Hesperocidaris perplexa H. L. Clark, Mortensen, Monogr. Echin. I. Cidaroidea, p. 421, pl. 42, fig. 14; pl. 73, fig. 7; pl. 82, figs. 30-31, 1928. Gulf of California in 65-70 meters. Clarion Island (locality perhaps not reliable).—H. L. Clark, Allan Hancock Pac. Exped., Vol. 8, No. 5, p. 231, pl. 36, fig. 3, December 29, 1948. South of San Benito Islands and the Gulf of California. Bahia Honda, Panama, north of Gorgona Island, Colombia, and La Plata Island, Ecuador, Recent.

Cidaris sp., Grant and Hertlein, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 2, p. 7, April 19, 1938. "Pacific Beach," Pliocene.

TYPE SPECIMEN: No. 188, Museum of Comparative Zoology, Harvard University.

TYPE LOCALITY: "Two of the five known specimens of this species were collected by the 'Álbatross' in the Gulf of California on a bottom of coarse sand, in 36-39 fathoms. The other three are said to have been picked up on the shore of Clarion Island, the westernmost of the Revilla Gigedo Islands." According to H. L. Clark (1948) the type locality is "Gulf of California."

RANGE: Middle Pliocene to Recent. Recent from south of the San Benito Islands to Lat. 29°39′N. in the Gulf of California, and from Bahia Honda, Panama, to La Plata Island, Ecuador, in 13 to 110 meters (7 to 60 fathoms).

OCCURRENCE IN THE SAN DIEGO FORMATION: CALIFORNIA ACADEMY OF SCIENCES: Loc. 1183, Eagle Street, just north of Quince Street, just east of Reynard Way, (spines); Loc. 1401, south slope of Soledad Mountain, first canyon west of Rose Canyon, (spines); Loc. 28892, near Mexican boundary, (spine); Loc. 28893, corner of India and Upas streets, San Diego. (spines). LOS ANGELES COUNTY MUSEUM: Loc. 122, 20 to 30 feet below end of Loring Street, Pacific Beach, (fragment and spines); Loc. 180, 2220 block on east side of La Jolla Boulevard at intersection with Trias Street, back of excavation, (spine). SAN DIEGO SOCIETY OF NATURAL HISTORY: Pacific Beach, (plate); Loc. 80, south slope of Soledad Mountain, first canyon west of Rose Canyon, (spines); Loc. 150, Pacific Beach, (spines). UNIVERSITY OF CALIFORNIA: Loc. A-8333, 2400 feet east and 1350 feet south of the northwest corner of Sec. 8, T.19S., R.2W., San Bernardino Base and Meridian (see U. S. Geol. Surv. topographic map, San Ysidro quadrangle, ed. 1943), (spines).

ORIGINAL DESCRIPTION: Test somewhat flattened; vertical diameter, about .55 h. d.; coronal plates 7 or 8; areolae small, only .60-.65 of horizontal length of plate, distinct and not very deeply sunken; median interambulacral area very fully covered with tubercles, smallest next to vertical suture, which is quite distinct; ambulacra about one-third of interambulacra in width; poriferous zones, broad and little sunken; median ambulacral area with a double series of tubercles on each margin, inner much smaller, and between these, 3-6 irregular series of small tubercles which sometimes, but not always, conceal vertical suture; pores nearly horizontal, large, their horizontal diameter much exceeding vertical. Abactinal system about .40 h. d., nearly circular and clearly defined, flat and quite thickly covered with small secondary spines; genital plates rather large, nearly square or somewhat pentagonal, with pores near outer edge; ocular plates more or less triangular, with apex truncated, when in contact with anal system, either wholly excluded, or some, or all except right anterior one, in contact with a large anal plate; anal system about one-half of abactinal, with an external series of 10-12 large plates and 12-15 smaller ones at centre; except along margins all plates of abactinal system covered with rather coarse tubercles of nearly uniform size; each genital plate has 50-80± such tubercles and each ocular 20-35±. Actinostome small, only about .35 h. d., not at all sunken, closely covered with stout plates, 4 in each interambulacrum and about 10 pairs in each ambulacrum. Primary spines short, about equal to h. d., nearly cylindrical, seldom tapering, but often flattened and widened at tip, covered with 14-24 longitudinal series of coarse, sharp granules; actinal primaries much as in Cidaris and nearly smooth; secondaries, long and narrow, but rather thick and often with a deep longitudinal furrow on outer surface at tip, which is thus crescent-shaped in cross-section. Pedicellariae not peculiar; no large globiferous ones were found, but small globiferous and tridentate, like those of *dubia*, are frequent. General color of test decidedly greenish, especially abactinally; miliary spines greenish; secondary spines greenish with a broad longitudinal stripe of deep reddish-purple; primary spines dull grayish with a bright olive-green base and collar. Largest specimen, 50 mm. h. d.; vertical diameter, 27 mm.; abactinal system, 20 mm.; actinostome, 18 mm.; longest spine, 40 mm., 3 mm. thick at base, 5 mm. wide at tip. (H. L. Clark.)

REMARKS: This species, cited as *Cidaris* sp. by the present authors in 1938, is represented by a fairly well-preserved plate from Pacific Beach in the collections of the San Diego Society of Natural History and by numerous spines in this and other collections available to us. Mr. Fred C. Ziesenhenne carefully compared these with a series of specimens in the Allan Hancock Foundation. According to him, if we allow for changes due to weathering and fossilization, these agree in all particulars with specimens of the Recent *Hesperocidaris perplexa* H. L. Clark. Comparison with specimens of the Recent species leads the authors to the same conclusion. A number of spines similar to those mentioned above are present in the collections of the California Academy of Sciences from various localities in San Diego and also in the collection of the Los Angeles County Museum.

H. L. Clark (1948) mentioned that the tests of large adult specimens attain a diameter of about 43 mm. and a height of 25 mm., with primary spines 35 to 43 mm. in length. He pointed out that the spines of this species do not show the characteristic flattening and widening at the distal end until they attain a length of about 30 mm. Some of the fossil spines in the present collections are similarly flattened.

This species differs from the related Recent west American species *H. dubia* H. L. Clark and *H. panamensis* A. Agassiz[84] in the smaller peristome and apical system, in the close tuberculation of the interporiferous zone, and in the distally widened and flattened primary spines. H. L. Clark pointed out (1948) that "the striking and very constant feature of the coloration in *perplexa* is the conspicuous broad, brown longitudinal stripe which occurs on *all* the spinelets." Mortensen considered "the character of the large globiferous pedicellariae lacking the limb on the stalk" to be important in the classification of this species.

Among the spines of *Eucidaris* cf. *E. thouarsii* collected by H. Hemphill from Pliocene beds at Pacific Beach, there are several which in general characters resemble those of *Hesperocidaris panamensis* A. Agassiz. The largest of these (incomplete) measures 34 mm. in length and 3.6 mm. in diameter. These spines were compared by Mr. Fred C. Ziesenhenne with those of Recent specimens of *H. panamensis* in the collections of the Allan Hancock Foundation. He stated that the fossil spines differ only in size from those of the Recent form. The difference in size, and the fact that no test referable to *H. panamensis* has been found, have led us merely to mention their occurrence here rather than to discuss them under a separate caption.

Hesperocidaris merriami Arnold[85] is represented by spines in the Martinez formation, Paleocene, in San Mateo County, California. These are quite similar to the spines of *H. perplexa,* but they bear only 13 or 14 longitudinal rows of spinules. H. L. Clark considered this Paleocene species to be the precursor of *H. perplexa.*

Hesperocidaris lorenzanus Kew[86], described from beds referred by Arnold to the San Lorenzo formation, Oligocene, was based upon spines. The spines are smaller than those of *H. merriami,* smooth toward the base, and ornamented above with fewer (about 10) but much more prominently nodose longitudinal ribs. According to H. L. Clark (quoted by Arnold), this species probably is referable to the same genus as *H. perplexa.*

A characteristic feature of *Hesperocidaris asteriscus* H. L. Clark (1948), from Panama, is said to be the star-like figure formed by the genital plates.

A portion of a spine from Loc. 1400 (CAS), Pacific Beach, differs from spines of *H. perplexa* in possessing more rows of closely compacted spinules. Mr. Ziesenhenne suggested that this might represent a rapidly developing juvenile spine but that it could hardly be referred to *H. perplexa.*

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(84) For reference to this species see p. 104.

(85) *Cidaris merriami* Arnold, Proc. U. S. Nat. Mus., Vol. 34, No. 1617, p. 359, pl. 32, fig. 8, August 8, 1908. "Santa Cruz quadrangle, San Mateo County, locality No. 25, ridge between headwaters of San Lorenzo River and Pescadero Creek." "Martinez formation, lower Eocene."

(86) *Cidaris branneri* Arnold, Proc. U. S. Nat. Mus., Vol. 34, No. 1617, p. 363, pl. 33, fig. 5, August 8, 1908. "Santa Cruz quadrangle, Santa Cruz County, locality No. 109, on Bear Creek, 4 miles above its confluence with the San Lorenzo River." "San Lorenzo formation, Oligocene, upper portion transitional toward Vaqueros formation, lower Miocene." (Not *Cidaris branneri* White, 1888, Brazil, Cretaceous.) Renamed *Cidaris lorenzanus* Kew, Univ. Calif. Publ. Bull. Dept. Geol., Vol. 12, No. 2, p. 52, pl. 3, fig. 4, 1920.

Order ARBACIOIDA Gregory

Family ARBACIIDAE Gray

Teeth keeled; ambulacral plates compound, with 3-5 elements in each plate; primordial interambulacral plates present; periproct with (normally) 4 or 5 equal plates; primary tubercles imperforate. (H. L. Clark, 1925.) Late Jurassic to Recent.

Genus ARBACIA Gray

Arbacia Gray, Proc. Zool. Soc. London for 1835, p. 58, June 1, 1835. Original list includes "*Arbacia pustulosa* (*Echinus pustulosus*, Lam.), *Arb. punctulata* (*Ech. punctulatus*, Lam.), &c."—Lambert and Thiéry, Essai Nomencl. Raison. Echinoid., Fasc. 4, p. 270, March, 1914. "Type: *A. pustulosa* Klein (*Cidaris*)."—H. L. Clark, Cat. Rec. Sea-Urchins Brit. Mus., p. 69, 1925. "Type, *Cidaris pustulosa* Leske, 1778 = *Echinus lixula* Linné, 1758. Syst. Nat., ed. 10, p. 664."—Mortensen, Monogr. Echin. II. Bothriocidaroida, Melonechinoida, Lepidocentroida, and Stirodonta, p. 562, 1935. "Genotype: *Cidaris pustulosa* Leske = *Echinus lixula* Linnaeus."—Grant and Hertlein, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 2, p. 18, April 19, 1938. Earlier records cited. "Type of the genus (according to H. L. Clark, 1908): *Cidaris pustulosa* Leske."

Synonyms of this genus cited by Mortensen are: *Echinocidaris* Desmoulins, 1835; *Agarites* L. Agassiz, 1841; *Anapesus* Holmes, 1860; *Pygomma* Troschel, 1872.

TYPE SPECIES (designated by H. L. Clark, Mem. Mus. Comp. Zool., Vol. 34, No. 2, p. 67, 1908): "Type-species, *Cidaris pustulosa* Leske, 1778." [*Cidaris pustulosa* Leske, Add. ad Klein, p. 150, pl. 11, figs. A-D, 1778. Also illustrated by A. Agassiz, Illustr. Cat. Mus. Comp. Zool., No. 7, (Mem. Mus. Comp. Zool., Vol. 3), Pt. 1, p. 92; Pt. 2, p. 263, pl. 2, fig. 4; pl. 5, figs. 1-18, 1872. Atlantic Ocean. "Littoral,—125 fathoms." Pt. 3, p. 402, pl. 1g, fig. 5; pl. 2a, figs. 15-33; pl. 5, figs. 19-21; pl. 28, fig. 6; pl. 38, figs. 10a-c, 1873. "Mediterranean; Liberia; Brazil." —Mortensen, Monogr. Echin. II, p. 566, pl. 70, fig. 13; pl. 87, figs. 11, 12, 1935 (placed under *Arbacia lixula* Linnaeus).]

RANGE: Late Miocene[87] to Recent. Pliocene to Recent in the western Americas. Recent on the west and east coasts of the Americas, Angola, Africa, to the Mediterranean, and Tristan da Cunha Island in the south Atlantic. Bathymetric range, intertidal zone to 315 meters (172 fathoms) (according to Mortensen). Most species occur in less than 182 meters (100 fathoms).

DESCRIPTION: Test solid, of medium size, up to c. 70 mm. diameter, low hemispherical or subconical, flattened on the oral side. Ambulacra with compound, 3-geminate plates; pore-zone straight, narrow above the ambitus, conspicuously widened on the oral side. Primary ambulacral tubercles in a regular series throughout. Interambulacra with numerous primary tubercles, arranged in horizontal and vertical series; on the upper side there is mostly a conspicuous naked, but not sunken interambulacral space, only the outer series of tubercles reaching to the apical system, the other series generally disappearing at the ambitus or at some distance from the apical system. No secondary tubercles. Generally the epistroma is conspicuously developed and may be of a characteristic design. Apical system dicyclic or with one to three of the oculars insert. Ocular pores double. Peristome very large, the ambulacra protruding so as to form "ambulacral lips." Gill-slits rather deep and wide. Peristomial membrane naked, with numerous small plates imbedded. Primary spines moderately long, scarcely exceeding diameter of test, straight, cylindrical, stout, often flattened at the end, but not pointed; on the oral spines the cortex-layer is present as a small terminal "shoe" or "cap"; the ambital and upper spines without any cortex-layer. Pedicellariae tridentate, triphyllous and ophicephalous. Sphaeridia single, only one in each ambulacrum, placed in a small pit in the median line, close to the peristomial edge. Spicules usually smooth rods, widened and with some holes in the middle. Colour mostly dark, the denuded test as a rule beautifully coloured, reddish, purplish or greenish. (Mortensen, 1935.)

REMARKS: Six species and one subspecies of this genus were cited by Mortensen as occurring in the seas at the present time. Three species occur in west American waters between Newport Bay, California, and Cape Horn. One of these is well known in the Magellanic region; the other two occur in warm temperate and tropical waters, rarely below 91 meters (50 fathoms).

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(87) Cooke (Jour. Paleo., Vol. 15, No. 1, p. 11, 1941) cited *Arbacia aldrichi* Clark from beds of late Oligocene age, but later he placed this species in the genus *Arbia* Cooke (see Cooke, C. W., U. S. Geol. Surv., Prof. Paper 321, p. 21, 1959).

Arbacia incisa A. Agassiz

Plate 26, Figures 6, 8, 10

Echinocidaris incisa A. Agassiz, Bull. Mus. Comp. Zool., Vol. 1, No. 2, p. 20, August 15, 1863. Guaymas and Panama.

Arbacia incisa A. Agassiz, H. L. Clark, Bull. Amer. Mus. Nat. Hist., Vol. 32, p. 220, 1913. "San Josef" [San José] Island, San Esteban Island, and Agua Verde Bay, Gulf of California.—Grant and Hertlein, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 2, p. 19, pl. 4, fig. 1; pl. 30, fig. 13, April 19, 1938. Pliocene to Recent.—H. L. Clark, Allan Hancock Pac. Exped., Vol. 8, No. 5, p. 244, pl. 40, fig. 11, December 29, 1948. Numerous records from Newport Harbor, California, to the Middle Chincha Island, Peru, Recent.

Arbacia stellata (Blainville; ?Gmelin), Mortensen, Monogr. Echin. II, Bothriocidaroida, Melonechinoida, Lepidocentroida, and Stirodonta, p. 575, pl. 68, figs. 8-10; pl. 70, figs. 6-9; pl. 71, fig. 7; pl. 87, figs. 13, 14, February 22, 1935. Lower California to Peru and the Galapagos Islands, Recent.

TYPE SPECIMEN: "Cotype" (according to H. L. Clark), No. 467, Museum of Comparative Zoology, Harvard University.

TYPE LOCALITY: "Guayamas, Panama." According to H. L. Clark (1948, p. 246) the type locality is "Guaymas," Sonora, Mexico.

RANGE: Pliocene to Recent. Recent from Newport, California, (Ziesenhenne[88]), to the Middle Chincha Island, Peru, Lat. 13°39′15″S., from the littoral zone to 91 meters (50 fathoms).

OCCURRENCE IN THE SAN DIEGO FORMATION: CALIFORNIA ACADEMY OF SCIENCES: Pacific Beach.

ORIGINAL DESCRIPTION: Abactinal system very prominent, sutures between the plates well marked; tubercles large, spines short, stout, color yellowish-brown. (A. Agassiz.)

REMARKS: A single small test of an echinoid, 7.6 mm. in diameter and 3.8 mm. high, was collected at Pacific Beach by Professor E. Dean Milow, San Diego State College, who generously presented it to us. Mr. Fred C. Ziesenhenne compared this with young specimens of *Arbacia incisa* in the Allan Hancock Foundation. He stated that the ocular plates, pore pairs, tubercles, and other visible characters of the test, were similar to corresponding structures of the specimens of *A. incisa*. We therefore refer the test to that species.

This species is also known to occur as a fossil in Pliocene beds in Ecuador and probably in the Pliocene strata on Cedros Island, Mexico, and in Pleistocene beds at Magdalena Bay, Lower California, Mexico, and in Ecuador.

Mortensen (1935) presented arguments for placing *Arbacia incisa* in the synonymy of *Echinus stellatus* Blainville [89] and perhaps in the earlier *Echinus stellatus* Gmelin[90]. H. L. Clark (1948) stated, "Nobody knows to what sea-urchin the name *stellatus* was first given." In an earlier paper, however, H. L. Clark[91] also used the name *Arbacia stellata* for the present species. In view of the doubtful application of the name *Echinus stellatus* as used by Agassiz and by Blainville, we use the name *Arbacia incisa*, which is well known to west American authors.

The largest recorded size for this species, cited by H. L. Clark, is a diameter of 60 mm. It is the only species of *Arbacia* in west American waters north of Ecuador. The tests of Recent specimens are readily identified by the reddish patches on the bare interambulacral areas on the aboral surface.

The test of Recent *Arbacia dufresnii* Blainville is greenish on the interambulacral areas. The ocular plates are wide and concave distally, and there are but few spines and tubercles on the aboral interambulacral areas. This species occurs from La Plata, Ecuador, to Puerto Mont on the coast of Chile and at the antarctic island of Booth Wandel and at the Falkland Islands.

The test of *Arbacia spatuligera* Valenciennes lacks red or green coloration, and it has club-shaped spines on the aboral surface. It ranges from Guayaquil, Ecuador, to southern Chile.

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(88) Ziesenhenne, F. C., Bull. South. Calif. Acad. Sci., Vol. 40, Pt. 3, pp. 118-120, September-December, 1941, issued January 31, 1942.

(89) *Echinus stellatus* Blainville, Dict. Sci. Nat., Vol. 37, p. 76, 1825. "J'ai établi cette espèce d'après un individu de la collection du Muséum, confondu à tort avec l'O. piqueté de M. de Lamarck."

(90) *Echinus stellatus* Gmelin, Syst. Nat., ed. 13, Tom. 1, Pars VI, p. 3174, 1788. "Habitat in mari americano." Ref. to "Seb. mus. 3.t.13, f.7."

(91) See Bull. Mus. Comp. Zool., Vol. 52, No. 17, p. 345, October, 1910.

Order ECHINOIDA Claus

Suborder CAMARODONTA Jackson

Family ECHINIDAE Gray

Ambulacral plates compound, typically of 3 elements; ambitus circular; test without sculpturing or pits (H. L. Clark, 1925.) Late Paleogene to Recent. (Durham and Melville.)

Genus LYTECHINUS A. Agassiz

Lytechinus A. Agassiz, Bull. Mus. Comp. Zool., Vol. 1, p. 24, August 15, 1863. Three species cited under the genus. "*Lytechinus carolinus* Ag." "South Carolina, Georgia, and Florida"; "*Lytechinus variegatus* A. Ag." "Cienfuegos, Hayti"; "*Lytechinus atlanticus* A. Ag." "Bermudas."—Grant and Hertlein, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 2, p. 23, 1938. "Type of genus (designated by Verrill, 1867): *Echinus variegatus* Leske."—Mortensen, Monogr. Echin. III.2. Camarodonta. I., p. 434, February 22, 1943. "Genotype: *Lytechinus variegatus* (Lamarck)."

TYPE SPECIES (designated by Verrill, Trans. Connecticut Acad. Arts and Sci., Vol. 1, Pt. 2, p. 302, 1867): "The *Echinus variegatus* may be regarded as the type." [Leske, Add. ad Klein, pp. xviii, 149, pl. 10, figs. B, C, 1778. Illustrated by Mortensen, 1943, p. 437, pl. 24, figs. 3-5; pl. 25, figs. 1-12; pl. 53, figs. 1, 6, 7, 11-13 (as *Lytechinus variegatus*). Common over all the West Indian region; north to North Carolina and Bermuda and south to Santos, Brazil.]

RANGE: Early Miocene to Recent. Recent, eastern Pacific, West Indies, west Atlantic, and Cape Verde Islands, in warm temperate and tropical waters, from the intertidal zone to 540 meters (295 fathoms).

DESCRIPTION: Buccal membrane usually heavily plated; a primary tubercle on each ambulacral plate; gill cuts deep; ocular I, and sometimes V, insert, as a rule. (H. L. Clark, 1925.)

REMARKS: *Lytechinus* was included in the family Echinidae by H. L. Clark, who discussed the problems of its classification (1925, pp. 104-105); but Mortensen (1943) placed it in the family Toxopneustidae Troschel. Tests range from small to quite large. The tests usually are low and rounded, and the ambulacra contain trigeminate plates, each with a primary tubercle. There is usually a bare median space in the aboral portion of each interambulacral area.

A specimen from early Miocene strata on Santa Rosa Island, California, was identified by H. L. Clark as very near to *Lytechinus pictus* Verrill, differing only slightly in details of tuberculation. Lack of details on fossil specimens led Mortensen to question whether some should be referred to *Lytechinus*. He mentioned, however, (1943, p. 435) that *L. coreyi* Grant and Hertlein, described from early Miocene beds in California, is probably the forerunner of the Recent west American species.

Mortensen cited ten species and subspecies in his key to the Recent species of *Lytechinus*. These are restricted to warm temperate and tropical waters. The four eastern Pacific species range from Santa Barbara, California, to Ecuador and the Galapagos Islands. The Atlantic species range from North Carolina and Bermuda Island to Santos, Brazil, and one species reaches the Cape Verde Islands.

Lytechinus species

OCCURRENCE IN THE SAN DIEGO FORMATION: LOS ANGELES COUNTY MUSEUM: Loc. 122, 20 to 30 feet below end of Loring Street, Pacific Beach.

REMARKS: A fragment of an echinoid test, 40 mm. in diameter, and a piece of a spine, were collected by J. F. Arndt at Loc. 122 (LAM), Pacific Beach. Both bear a general resemblance to *Lytechinus pictus* Verrill[92]. These were examined by Mr. Fred C. Ziesenhenne, who stated that the observable plates, bearing three pore pairs in each arc, and the spine, resemble comparable portions of *L. pictus*. He added, however, that the fossil is larger than any Recent specimen of that species in the collections of the Allan Hancock Foundation.

The fossil specimen is so incomplete and so imperfectly preserved that no illustration is given. It seems desirable, however, to record the presence of the genus *Lytechinus* in the San Diego formation.

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(92) *Psammechinus pictus* Verrill, Trans. Connecticut Acad. Arts and Sci., Vol. 1, Pt. 2, p. 301, June, 1867. "Cape St. Lucas, Cal.,—J. Xantus, (Smithsonian Institution)."—Grant and Hertlein, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 2, p. 25, pl. 5, figs. 4-6; pl. 15, figs. 6, 7, 1938. Miocene to Recent.—Mortensen, Monogr. Echin. III. 2. Camaradonta.I., p. 450, pl. 53, figs. 2, 8, 1943.—H. L. Clark, Allan Hancock Pac. Exped., Vol. 8, No. 5, p. 249, pl. 41, fig. 15, 1948. Newport, California, to the Gulf of California and perhaps south to Gorgona Island, Colombia, and La Plata, Ecuador, (although the records of occurrences at the two latter localities may represent *L. panamensis* Mortensen) in 0 to 95 fathoms.

Lytechinus pictus has been recorded as occurring in Pliocene strata on Cedros Island, Lower California, Mexico.

Family STRONGYLOCENTROTIDAE Gregory

Ambitus circular; no pits or sculpturing on the coronal plates; ambulacral plates compound, usually with 4 or more elements (rarely 3). (H. L. Clark, 1925). Miocene to Recent.

Genus STRONGYLOCENTROTUS Brandt

Strongylocentrotus Brandt, Rec. Actes Séance Publ. Acad. Impér. Sci. St. Petersbourg for 1834, p. 263 (in separate p. 63), issued 1835. Species in original list: *Echinus chlorocentrotus* Brandt (p. 264) and *?Echinus tuberculatus* Blain. (p. 264).—H. L. Clark, Mem. Mus. Comp. Zool., Vol. 34, p. 352, 1912. "Type-species, *Strongylocentrotus chlorocentrotus* Brandt, l.c., p. 264 (or 64) = *Echinus dröbachiensis* O. F. Müller, 1776."—Grant and Hertlein, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 2, p. 31, 1938. Type (by virtual monotypy): *Strongylocentrotus chlorocentrotus* Brandt (= *Echinus dröbachiensis* O. F. Müller).—Mortensen, Monogr. Echin. III. 3. Camarodonta. II., p. 193, October 1, 1943. "Genotype: *Strongylocentrotus chlorocentrotus* Brandt = *drøbachiensis* (O. Fr. Müller)."

Euryechinus Verrill, Proc. Boston Soc. Nat. Hist., Vol. 10, pp. 340, 341, 1866. "A new name must be adopted for the present group, having *E. dröbachiensis* as its type."

TYPE SPECIES [by virtual monotypy, *Strongylocentrotus chlorocentrotus* Brandt, 1835, p. 264 (= *Echinus dröbachiensis* O. F. Müller, Prod. Zool. Dan., p. 235, 1776)] (designated by the International Commission on Zoological Nomenclature in Opinion 208, March 8, 1954): *Echinus drøbachiensis* O. F. Müller. [Illustrated by A. Agassiz, Illustr. Cat. Mus. Comp. Zool., No. 7 (Mem. Mus. Comp. Zool., Vol. 3), Pt. 1, p. 162; Pt. 2, p. 277, 1872; Pt. 3, p. 441, pl. 4a, figs. 2, 3, 6, 1873. North Europe; North Pacific; northeast America. (Contains extensive synonymy.) —Mortensen, Danish Ingolf-Exped., Vol. 4, Pt. 1, Echin. (1), pp. 162, 165, pl. 1, figs. 5, 6; pl. 2, figs. 3-5; pl. 16, figs. 4, 9, 11, 13, 17, 21, 23; pl. 20, figs. 3-6, 12, 13, 16, 18, 20, 25, 26, 29, 1903. Wide distribution in the North Atlantic and North Pacific Oceans. —Grant and Hertlein, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 2, p. 33, pl. 4, fig. 6; pl. 6, fig. 1, 1938. North Europe; North Pacific; northeast coast of North America. —Mortensen, Monogr. Echin. III.3. Camarodonta. II., p. 198, figs. 92a, b, 93a, 95; pl. 23, figs. 1-11; pl. 69, figs. 1-5, 10, October 1, 1943. (With synonymy.) Circumpolar; to Puget Sound in western North America and to northern Scotland in the Atlantic.]

RANGE: Miocene of Oregon (Arnold). Pliocene to Recent in California and Lower California. Recent, North Pacific, and one species circumboreal and ranging to northern Scotland and to Chesapeake Bay, from the littoral zone to 1600 meters (875 fathoms); off California, littoral zone to 125 meters (68 fathoms).

ORIGINAL DESCRIPTION: Aculei teretes, subulati, conformes et magnitudine tantum inaequales. (Brandt.)

SUPPLEMENTARY DESCRIPTION: Pore pairs 4 to 10, but usually not more than 7; valve of globiferous pedicellariae with a powerful end tooth but no lateral teeth. (H. L. Clark, 1925.)

REMARKS: *Strongylocentrotus* is widespread in the northern seas at the present time. This genus is characteristic of cold and temperate waters, but in west American waters ranging south to San Bartolomé Bay (Turtle Bay), Lower California. Mortensen included ten living species in the genus, only one, the type of the genus, ranging through the Arctic seas and into the North Atlantic as far as Scotland. This distribution, states Mortensen, strongly points toward a North Pacific origin of *Strongylocentrotus*.

Species attributed to *Strongylocentrotus* have been cited from Miocene strata in France, but according to Mortensen these probably are referable to *Paracentrotus* Mortensen. Cooke (1941, p. 19) indicated that the record (Clark and Twitchell, 1915) of the occurrence of *Strongylocentrotus dröbachiensis* in the Caloosahatchie beds of Pliocene age in Florida needs confirmation.

Two species of *Strongylocentrotus* occur off California in shallow depths, generally among rocks up to the intertidal zone but sometimes to depths of 161 meters (88 fathoms). Swan[93] recently discussed the species of this genus occurring in the waters of the northeast Pacific.

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(93) Swan, E. F., "The Strongylocentrotidae (Echinoidea) of the Northeast Pacific," Evolution, Vol. 7, No. 3, pp. 269-273, September 30, 1953. See also "Regeneration of Spines by Sea Urchins of the Genus Strongylocentrotus," Growth, Vol. 16, pp. 27-35, 1952.

The species from southern California described as *Strongylocentrotus fragilis* Jackson[94] has been referred by some later workers to *Allocentrotus* Mortensen; this occurs in deeper water, often 73 to 110 meters (40 to 60 fathoms) but sometimes as deep as 1170 meters (640 fathoms) (H. L. Clark, 1948.)

The diagnostic characters of this genus cited in Mortensen's key to the family Strongylocentrotidae are as follows: ambulacra gradually constricted on the oral side, at the peristomial edge distinctly narrower than the interambulacra; spicules of the globiferous pedicellariae simply bihamate; test very fragile.

KEY TO THE SPECIES OF STRONGYLOCENTROTUS

A. Primary spines very long (50-60 mm.); test usually exceeding 75 mm. in diameter; 2 rows of primary tubercles in each interambulacrum decidedly larger than adjacent ones; arcs of 9-10 pore pairs, steeply sloping.....*franciscanus*

B. Primary spines short. usually not exceeding 15-20 mm.; test usually not exceeding 75 mm. in diameter; 2 rows of primary tubercles in each interambulacrum not exceptionally larger than adjacent ones; arcs of usually 8 pore pairs, approaching horizontal arrangement.....*purpuratus*

Strongylocentrotus franciscanus A. Agassiz

Plate 19, Figure 28

Toxocidaris franciscanus A. Agassiz, Bull. Mus. Comp. Zool., Vol. 1, p. 22, August 15, 1863. San Francisco, California. Recent.

Strongylocentrotus franciscanus A. Agassiz, A. Agassiz, Illustr. Cat. Mus. Comp. Zool., No. 7 (Mem. Mus. Comp. Zool., Vol. 3), Pt. 1, p. 163 (in part), 1872; Pt. 3, p. 442 (in part); pl. 5b, figs. 1, 2; pl. 7, figs. 10, 10a, 1873. Localities cited from Puget Sound to San Diego, California, Recent.—Kew, Univ. Calif. Publ. Bull. Dept. Geol., Vol. 12, No. 2, table opp. p. 52, 1920. "San Diego," "Pliocene." (Not pl. 4, figs. 1a-c = *?Echinometra van-brunti* A. Agassiz).—Grant and Hertlein, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 2, p. 34, fig. 14; pl. 2, fig. 6; pl. 6, fig. 3, 1938. "San Diego (Kew)".—Mortensen, Monogr. Echin. III.3. Camarodonta.II., p. 242, figs. 106-110; pl. 28, figs. 1-7; pl. 29, figs. 1-4; pl. 30, figs. 2-3; pl. 31, figs. 1-2; pl. 32, figs. 1-3; pl. 61, figs. 10, 15-19, 23, October 1, 1943. Kodiak Island, Alaska, to Cedros Island, Lower California, and northern Japan, Recent.

TYPE SPECIMEN: "Cotype" (according to H. L. Clark, 1948) No. 1686, Museum of Comparative Zoology, Harvard University.

TYPE LOCALITY: "San Francisco," California. Recent.

RANGE: Middle Pliocene to Recent. Recent from Kodiak Island, Alaska, to Cedros Island and Thurloe Point, Lower California, Mexico. (?)Hakodate, Japan (see Mortensen, 1943, p. 246). From the littoral zone to 125 meters (68 fathoms) (Mortensen).

OCCURRENCE IN THE SAN DIEGO FORMATION: San Diego (Kew; Grant and Hertlein). CALIFORNIA ACADEMY OF SCIENCES: Loc. 12163, Pacific Beach. LOS ANGELES COUNTY MUSEUM: Loc. 305, 2400 feet east and 1350 feet south of the northwest corner of Sec. 8, T.19S., R.2W., San Bernardino Base and Meridian (see U. S. Geol. Surv. topographic map, San Ysidro quadrangle, ed. 1943). UNIVERSITY OF CALIFORNIA: Loc. A-8333, locality same as Loc. 305 (LAM). UNIVERSITY OF CALIFORNIA AT LOS ANGELES: corner of Market Street and Euclid Avenue, San Diego (fragment) (B. Brattstrom coll.).

ORIGINAL DESCRIPTION: This species grows to a very large size. High coronal plates, large openings for suckers. Pores arranged in arcs of nine pairs. Two very prominent rows of large tubercles in interambulacral space. The large tubercles of ambulacra of same size as secondary of interambulacra. Spines long, tapering gradually, equalling in length two thirds the diameter of test. (A. Agassiz.)

REMARKS: Portions of two small tests, the larger about 21.5 mm. in diameter, were collected by Henry Hemphill at Loc. 12163 (CAS), Pacific Beach. A comparison of these with specimens of *Strongylocentrotus franciscanus* of similar size reveals no appreciable differences.

A fragment of a test, (UCLA coll.), 25.5 mm. in altitude and 15 mm. in diameter, from Market Street and Euclid Avenue in San Diego, appears to represent a portion of a basal ambulacrum of the present species. In the size and arrangement of the pore pairs and in the slope of the arcs, this fragment is very similar to corresponding parts of Recent specimens of *Strongylocentrotus franciscanus*.

A fragment of a spine 14.8 mm. in length from Loc. A-8333 (UC), from southwestern San Diego County, appears to be referable to this species. It occurs with a fragment of a spine of *Hesperocidaris*.

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[94] *Strongylocentrotus fragilis* Jackson, Mem. Boston Soc. Nat. Hist., Vol. 7, p. 128, January, 1912. ". . . at Catalina Island, off the southern California coast. . ." Also "dredged off the coast of southern California and Oregon in depths of 124 to 339 fathoms."—Grant and Hertlein, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 2, p. 34, pl. 29, fig. 1, 1938. Vancouver Island, British Columbia, to Point Santa Eugenia, west coast of Lower California in deep water.—Mortensen, Monogr. Echin. III.3. Camarodonta. II., p. 255, pl. 30, figs. 10-17; pl. 61, figs. 4, 5, 7, 11, 12, 14, text figs. 117-119, October 1, 1943 (as *Allocentrotus fragilis*). Ca. 50-1150 meters.

Spines of *S. franciscanus* also are present in collections of the Los Angeles County Museum from this locality, Loc. 305 (LAM).

The tests of large specimens of *Strongylocentrotus franciscanus* attain a diameter of 160 mm., and some have been recorded which, with the spines, measured a foot in diameter. The spines of this species are light reddish, brownish, or occasionally purple; on young specimens the tips are white but not banded.

Strongylocentrotus franciscanus differs from *S. purpuratus,* with which it sometimes occurs at the present time, in that the test is much larger, the primary spines are much longer (50 to 60 mm.), and the arcs of pore pairs are more nearly vertical and consist of 9 or 10 rather than about 8 pore pairs. Furthermore, in the midzone of each interambulacrum are two rows of very large tubercles, each row flanked on each side by a row of smaller tubercles: thus each coronal plate has three prominent tubercles, the middle one largest. The corresponding tubercles on *S. purpuratus* are much more nearly uniform in size. Also, *S. franciscanus* has fewer coronal plates: at a diameter of 60 mm. it has 16 or 17, whereas *S. purpuratus* of the same size has about 28 to 30. Mortensen considered *S. franciscanus* to be closely related to *S. nudus* A. Agassiz, of Japan.

Mortensen (1943, p. 242-247) gave a full discussion of the morphology and distribution of this species. He pointed out that individuals living in surf have spines shorter and thicker than are those of individuals living in calm water.

Swan[95] mentioned that this species, in the Puget Sound region, often occurs abundantly a few feet below tide level on vertical faces of rock. He stated that it occurs on intertidal rocky areas on San Juan Island and Lopez Island, Washington, often with *S. purpuratus* and *S. dröbachiensis* as well as with what are probably hybrids of these species. *S. franciscanus* occurs abundantly in rocky places along the coast of northern and central California, generally in deeper tide pools than does *S. purpuratus.* It is said to have been used for food at times by the Indians and Greeks along the coast of British Columbia.

Strongylocentrotus purpuratus Stimpson

Plate 19, Figure 29

Echinus purpuratus Stimpson, Boston Jour. Nat. Hist., Vol. 6, p. 526, April, 1857. "Near San Francisco."

Strongylocentrotus purpuratus Stimpson, Arnold, U. S. Geol. Surv., Prof. Paper 47, p. 28, 1906. "Pacific Beach," "San Diego formation," Pliocene.—W. B. Clark and Twitchell, U. S. Geol. Surv., Monogr. 54, p. 223, 1915. "San Diego formation (upper part), Pliocene."—Kew, Univ. Calif., Publ. Bull. Dept. Geol., Vol. 12, No. 2, opp. p. 52, p. 58, 1920. "Pacific Beach, San Diego County," Pliocene.—Grant and Hertlein, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 2, p. 37, pl. 4, figs. 4 and 5; pl. 6, fig. 2; text figs. 13 and 15, 1938. "Pliocene.—San Diego, California." Also earlier records cited.—Mortensen, Monogr. Echin. III.3. Camarodonta.II., p. 236, figs. 102b, 103b, 105; pl. 26, figs. 1-8; pl. 27, figs. 5, 7-9; pl. 32, fig. 4; pl. 61, figs. 6, 20-22, 24, October 1, 1943. Vancouver Island, and perhaps Sitka, Alaska, to Cedros Island, Lower California, from littoral zone to about 20 meters.

TYPE SPECIMEN: No. 2495, United States National Muesum.

TYPE LOCALITY: "Found at low-water mark on rocky ocean shores near San Francisco." California.

RANGE: Questionably in the middle Miocene of Oregon ("cf." Arnold, 1906); Pliocene to Recent in California. Recent from Sitka, Alaska (Rathbun; see Mortensen, 1943, p. 241), and Puget Sound, Washington, to Cedros Island, Lower California, Mexico, from the littoral zone to about 20 meters (11 fathoms).

OCCURRENCE IN THE SAN DIEGO FORMATION: San Diego formation (Arnold; Clark and Twitchell); Pacific Beach (Kew): San Diego, earlier records (Grant and Hertlein). LOS ANGELES COUNTY MUSEUM: Loc. 153, cliff 50 feet above sea level, south of the end of Loring Street, Pacific Beach; Loc. 305, 2400 feet east and 1350 feet south of the northwest corner of Sec. 8, T.19S., R.2W., San Bernardino Base and Meridian, (spines) (see U. S. Geol. Surv. topographic map, San Ysidro quadrangle, ed. 1943).

ORIGINAL DESCRIPTION: Form depressed. Outline somewhat pentangular. Ambulacral areas of the same width as the interambulacrals; (sometimes even wider;) with eight pairs of pores in each of the very oblique rows, which are separated from each other by rows of small tubercles. Interambulacral area with six rows of larger tubercles, between which smaller ones are interspersed; the tubercles of the two rows next within the exterior ones are largest. Auricles slender. Spines of moderate length, rather stout and blunt. Color, deep purple. Diameter, 2½ inches; height, 1 1/3 inch. (Stimpson.)

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[95] Swan, E. F., Evolution, Vol. 7, pp. 270, 271, 1953.

REMARKS: A portion of a single somewhat crushed test, 79.5 mm. in diameter and approximately 38 mm. in altitude, in the collections of the Los Angeles County Museum, is referable to this species. The character of the tubercles as well as the nearly horizontal arrangement of the pore pairs agrees with the corresponding portions of tests of Recent specimens of *Strongylocentrotus purpuratus.*

This specimen came from Loc. 153 (LAM), in a cliff 50 feet above sea level at Pacific Beach. According to the information concerning the locality, there was an element of doubt in the mind of the collector, W. C. Woynar, as to whether the specimen came from beds of Pliocene or of Pleistocene age. However, the brown indurated matrix in which the specimen was embedded is exactly similar to that of the Pliocene strata in that area, and accordingly we consider the specimen to be of Pliocene age.

Spines referable to *Strongylocentrotus purpuratus* also are in a collection of the Los Angeles County Museum from Loc. 305 (LAM), near the Mexican boundary.

This is a common purple sea urchin along the west coast of the United States. Occasionally adult, and especially young, specimens may be green, or the spines may be banded reddish and white. The test is often about 50 to 60 mm. in diameter but occasionally is larger. Swan mentioned specimens from San Juan Island, Washington, which measured from 89 to 99 mm. in diameter. The spines are much shorter than those of *S. franciscanus,* usually not exceeding about 20 mm. in length. The test is smaller than that of *S. franciscanus,* and there are usually about 8 pore pairs in each arc rather than 9 to 10, and these arcs are more nearly horizontal. Furthermore, the primary tubercles on the interambulacral areas of *S. purpuratus* are more nearly the same size as the adjacent ones than are those of *S. franciscanus,* and there are also more numerous coronal plates.

Swan[96] discussed the occurrence of this species in the Puget Sound region and mentioned that specimens occur there which appear to be hybrids between *S. purpuratus* and *S. dröbachiensis* and between *S. purpuratus* and *S. franciscanus.* The same author[97] pointed out that the regenerated spines of *S. purpuratus* are purple instead of the green color which juvenile specimens may have. Also, this species has a great preference for areas of rough water, and the test is tougher and heavier than those of *S. dröbachiensis* and *S. franciscanus;* consequently, it is best fitted for survival if torn loose and washed over rocks in the surf. According to Swan the spines regenerated by *Strongylocentrotus* do not have the same number of wedges or cycles as do the original spines.

Mortensen (1943, p. 236-242) gave a comprehensive discussion of the morphology and characteristics of this species. He stated that he had never seen hybrids between *S. purpuratus* and *S. dröbachiensis* and that he considered *S. purpuratus* to be quite a distinct species.

Mortensen (1943, p. 240) doubted the statement that *S. purpuratus* has the ability to bore cavities in rocks. Irwin[98] has shown that this species as well as *S. franciscanus* does form such cavities. She reported that on a pier near Santa Barbara, California, these urchins occupied circular depressions in steel piling and that the surface of the steel was rust-free and shiny beneath them and thus constantly exposed to the corrosive action of the sea water. Branner[99] long ago pointed out that even the hardest rocks are bored by sea urchins in Brazil.

The food of this species consists of algae and other organic material which it finds on the rocks. Some early accounts mention that this species was at one time sold in the markets of San Francisco, where it was purchased for food by Italian residents.

Family **ECHINOMETRIDAE** Gray

Ambitus more or less elliptical; no pits or sculpturing of coronal plates; ambulacral plates compound, with 3-19 elements, but usually more than 4; oculars exsert or becoming insert in sequence V, I, IV (not I, V, IV as usual). (H. L. Clark, 1925.) Middle Eocene to Recent.

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(96) Swan, E. F., Evolution, Vol. 7, p. 270, 1953.

(97) Swan, E. F., Growth, Vol. 16, pp. 32-34, 1952.

(98) Irwin, M., "Steel-Boring Sea Urchins," Pac. Discovery (Publ. Calif. Acad. Sci.), Vol. 6, No. 2, pp. 26, 27, 3 illustr., March-April, 1953.

(99) Branner, J. C., "Syllabus of a Course of Lectures on Elementary Geology," (Stanford University, California) ed. 4, p. 246, fig. 57, also pl. 18, 1912.

Genus ECHINOMETRA Gray

Echinometra Gray, Ann. Phil., Vol. 26 (n.s. 10), p. 426, 1825 (as of Bryerius [Breynius, 1732]). Species in original list: *E. lucunter* Linnaeus, *E. atratus* Klein, and *E. mammillatus* Klein.—H. L. Clark, Cat. Rec. Sea-Urchins Brit. Mus., p. 142, 1925. "Type, *Echinus lucunter* Linné."—Grant and Hertlein, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 2, p. 39, April 19, 1938. Type as indicated by Lambert and H. L. Clark.—Mortensen. Monogr. Echin. III.3. Camarodonta. II., p. 352, 1943. "Genotype: *Echinometra lucunter* (Linnaeus)."

Synonyms of this genus cited by Mortensen are: *Ellipsechinus* Lütken, 1864; *Plagiechinus* Pomel, 1883; *Mortensenia* Döderlein, 1906. There is an *Echinometra* of Meuschen, 1778, but this name has not been generally used.

TYPE SPECIES (designated by Lambert, Mém. Soc. Paléo. Suisse, Vol. 37, p. 48, 1911, and by H. L. Clark, Mem. Mus. Comp. Zool., Vol. 34, p. 370, 1912): *Echinus lucunter* Linnaeus. [Syst. Nat., ed. 10, p. 665, 1758. *"Habitat in* O. Indico." Ref. to Gualtieri, Index Test. Conchyl., pl. 107, fig. C (as *Echinus ovalis,* etc.), 1752. Also illustrated by Mortensen, 1943, p. 357, figs. 172-175, 177; pl. 41, figs. 1-5; pl. 42, figs. 12-14; pl. 43, figs. 1-13; pl. 44, fig. 9; pl. 64, figs. 17, 20-24. Florida to Desterra, Brazil; West Indies; Bermuda; St. Helena; Dakar to Angola, Africa.]

RANGE: Eocene[100] (Nummulitique de l'Inde) to Recent. Recent, in very warm temperate and tropical waters in the Pacific, Atlantic, and Indo-Pacific, from the intertidal zone to about 53 meters (29 fathoms).

DESCRIPTION: Test usually elongately oval, rather strong, moderately large to large, white or with tinge of purple or greenish; ambulacral plates of 4 to 8 elements; periproct with numerous plates; ambulacra with 3 pore pairs to each arc at the peristomial edge, the number increasing to 4 to 10 pore pairs above; auricles usually large; the primary spines moderately long, pointed, sometimes clavate, varying from brown to black, purple, or white. (Adapted from Mortensen and H. L. Clark.)

REMARKS: Adult members of this genus can usually be separated from those of *Strongylocentrotus* by the elongately oval test and by the large auricles. Juvenile forms may be but slightly elongated.

About six species and two or three varieties of this genus occur in the seas at the present time. Three species, *Echinometra insularis* H. L. Clark, *E. oblonga* Blainville, and *E. van-brunti* A. Agassiz occur in eastern Pacific waters.

The present authors (1938) pointed out that the genus *Echinometra* is represented in the Pliocene of Ventura County, California, by a specimen illustrated by Kew[101] under the name of *Strongylocentrotus franciscanus.* This specimen appears to be referable to *Echinometra van-brunti* A. Agassiz. The latter species also has been recorded as occurring in beds of late Pliocene age at Santa Barbara, California. The species described under the name of *Heliocidaris stenopora* H. L. Clark, from Acapulco, Mexico, is now believed to be identical with *Echinometra van-brunti.*

Echinometra species

Plate 26, Figures 4, 5

Echinometra sp., Grant and Hertlein, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 2, p. 41, April 19, 1938. "Lower beds of the San Diego Pliocene at Pacific Beach."

OCCURRENCE IN THE SAN DIEGO FORMATION: CALIFORNIA ACADEMY OF SCIENCES: Loc. 1413, lower beds of the Pliocene section at Pacific Beach.

REMARKS: A small, slightly crushed test 19.2 mm. in maximum diameter and 8.3 mm. in height, is in the collections of the California Academy of Sciences from Loc. 1413 (CAS), from Pliocene beds in the lower portion of the section exposed at Pacific Beach. The late H. L. Clark stated that the species was undeterminable but that the test appeared to be referable to the genus *Echinometra.* This generic assignment was recently confirmed by Mr. Fred C. Ziesenhenne at the Allan Hancock Foundation in Los Angeles.

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(100) See remarks by Mortensen, 1943, p. 355.

(101) *Strongylocentrotus franciscanus* A. Agassiz, Kew, Univ. Calif. Publ. Bull. Dept. Geol., Vol. 12, No. 2, pl. 4, figs. 1a-c, 1920.

Order CLYPEASTEROIDA L. Agassiz

Family DENDRASTERIDAE Lambert

Medium-sized to large, flattened, usually well-developed internal supports; petals well formed, a few isolated pores outside petals; paired petals more or less closed, anterior petal more widely open; outer member of pore-pair elongated; interambulacrum 5 discontinuous on oral surface; interambulacra nearly as wide as ambulacra at ambitus; basicoronal interambulacral plates larger than ambulacral plates; 4 genital pores; periproct inframarginal to supramarginal; ambulacral food grooves bifurcating or trifurcating just outside basicoronal plates. (Durham, 1955.) Pliocene to Recent, Pacific Coast of North America and Japan.

KEY TO THE GENERA OF DENDRASTERIDAE

A. Apical system usually decidedly eccentric posteriorly; paired petals usually partially closed; margins of test moderately thin ..... *Dendraster*

B. Apical system only slightly eccentric posteriorly; paired petals usually open; margins of test thick and rounded ..... *Merriamaster*

Genus DENDRASTER L. Agassiz

Dendraster L. Agassiz, in Agassiz and Desor, Ann. Sci. Nat. (Zool.), Ser. 3, Vol. 7, p. 135, 1847. Only species "*exeentricus* Agass.—*Echinarachnius excentricus* Val., Zool. Venus, pl. 10, Californie (Neboux).—Mus. Paris."—H. L. Clark, Mem. Mus. Comp. Zool., Vol. 46, p. 69, 1914. "Type, *Scutella excentrica* Eschscholtz."—Lambert and Thiéry, Essai Nomencl. Raison. Echinid., Fasc. 4, p. 319, 1914. "Type: *D. excentricus* Eschscholtz (*Scutella*)." See also Fasc. 9, p. 584, 1925.—Grant and Hertlein, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 2, p. 78, 1938. "Type of the genus (by monotypy): '*exeentricus* Agass.—*Echinarachnius exeentricus* Val., Zool. Venus. pl. 10, Californie'."—Durham, Univ. Calif. Publ. Geol. Sci., Vol. 31, No. 4, pp. 100, 158, 1955. "Type species: *Dendraster excentricus* L. Agassiz = *Scutella excentrica* Eschscholtz = *Echinarachnius excentricus* Valenciennes, monotypic."

Echinarachnius A. Agassiz, (in part), Illustr. Cat. Mus. Comp. Zool., No. 7, (Mem. Mus. Comp. Zool., Vol. 3), Pt. 1, p. 107; Pt. 2, p. 315, 1872; Pt. 3, p. 524, 1873.

Not *Echinarachnius* Gray, 1825.

TYPE SPECIES (by monotypy): "*exeentricus* Agass. —*Echinarachnius excentricus* Val., Zool. Venus. pl. 10, Californie." [= *Scutella excentrica* Eschscholtz, Zool. Atlas, Heft 4, p. 19, pl. 20, figs. 2a-c, 1831. "An der Küste der Insel Unalaschka, am Kamtschatischen Meere." —Grant and Hertlein, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 2, p. 84, figs. 16, 17, 1938 (with synonymy). —Mortensen, Monogr. Echin., IV.2. Clypeastroida. II, p. 382, fig. 222, pl. 60, figs. 1-5; pl. 61, figs. 1, 6; pl. 63, fig. 3, December 30, 1948. —Durham, Univ. Calif. Publ. Geol. Sci., Vol. 31, No. 4, figs. 1d, 4c, 5b, 11, 20, 21a, 21b, 26j, 33, 1955.]

RANGE: Early Pliocene to Recent. Most abundant in late Pliocene: known to occur from central California to the Gulf of California. Recent from the island of Unalaska, Alaska, to near Cape San Lucas, Lower California, Mexico. (Latter locality cited by H. L. Clark, 1948.) From the intertidal zone to about 91 meters (50 fathoms), perhaps occasionally deeper.

DESCRIPTION: Medium-sized to large, flattened; apical system often posteriorly excentric, raised; margins of test moderately thin; paired petals moderately closed, anterior petal elongated, more open than paired petals; a few isolated primary pores outside petals; periproct inframarginal, close to margin, between second and third pair of post-basicoronal plates; peristome central; ambulacral food grooves complexly developed, usually extending onto aboral surface, usually strongly developed posteriorly; basicoronal plates relatively small, interambulacral plates about twice as large as ambulacral plates; interambulacra all discontinuous on oral surface, separated by a pair of ambulacral plates; 3 or 4 post-basicoronal interambulacral plates to column on oral surface; posteriorly 5 or 6 and anteriorly 7 or 8 pairs of post-basicoronal ambulacral plates on oral surface. (Durham, 1955.)

REMARKS: The test of this genus is quite distinct from that of any other genus: it is characterized by the eccentric apical system with elongated anterior petal, by the thin margins, and by the inframarginal periproct. It is easily separated from *Scutellaster* Cragin by the eccentric apical system and the inframarginal rather than supramarginal periproct. *Scutellaster* Cragin is an earlier name for *Anorthoscutum* Lambert and Thiéry and for *Calaster* Kew. The synonymy of this genus has been discussed by Durham[102].

(102) Durham, J. W., "Scutellaster and Anorthoscutum," Jour. Paleo., Vol. 27, No. 1, pp. 147-149, 1 fig., January, 1953.

Eighteen species and subspecies of this genus have been recorded from the Pliocene and Pleistocene of California and Lower California. Fossil forms described since our paper on Echinoidea in 1938 are *Dendraster granti* Durham, from Pliocene strata on the east coast of Lower California, and *D. elsmerensis* Durham, from southern California.

Four species and one subspecies occur in west American waters. In addition to *Dendraster excentricus* Valenciennes and its variety *elongata* H. L. Clark, which were mentioned in our earlier paper, H. L. Clark (1948) has described three others. These are *Dendraster laevis* from north of Santa Barbara Island, California, in 27 to 37 meters (15 to 20 fathoms), *D. mexicanus* from Rosario Bay, Lower California, in 27 meters (15 fathoms), and *D. rugosus* from the Bay of San Sebastian Vizcaino, Lower California, in 31 meters (17 fathoms). The latter species appears to be identical with *D. vizcainoensis* Grant and Hertlein, which originally was described from Quaternary beach deposits at the same bay.

Durham (1955, p. 159), suggested that in *Dendraster* the eccentricity of the apical system and the degree of greater posterior development of the food grooves of a particular species may be correlated with the position assumed by individuals of the species, whether on edge, slightly tilted, or lying flat. He suggested that noneccentric species are probably those which lie flat upon the sea bottom.

On the basis of a statistical analysis of variation, especially in degree of eccentricity, Raup[103] concluded that two ecological races of *Dendraster excentricus* were recognizable. Individuals occurring in sheltered bays were less eccentric than those occurring on open coasts. However, he found no systematic geographic variation based upon this character.

There is certainly much variation in many of the species in this genus, but the characters relied upon for specific differentiation by Kew, by Woodring, and by Stewart, taken together with the stratigraphic occurrence of the specimens, appear to justify such specific discrimination.

H. L. Clark (1948) reported specimens of *Dendraster excentricus* from the coast of Oregon that measured 75 mm. in length, 80 mm. in width, and 12 to 14 mm. in height. A large specimen of *Dendraster venturaensis* Kew, collected by Margaret Bennett and C. M. Carson from strata of late Pliocene age on the ridge west of Coles Canyon, Ventura County, California, measures 100 mm. in length (anteroposterior), 112 mm. in width.

Individuals of *Dendraster* often live on fine sandy bottoms over which tidal currents flow, crowded together, more or less steeply inclined, and with the anterior fourth of the test buried in the sand. They occur abundantly from intertidal sands to a depth of about 37 meters (20 fathoms) and then become less abundant to a depth of about 91 meters (50 fathoms) or perhaps occasionally deeper.

Observations on pigments of *Dendraster excentricus* and *D. laevis* have been recorded by Goodwin and Fox[104].

KEY TO THE SPECIES OF DENDRASTER

A. Apical system only slightly eccentric posteriorly; petals slightly raised ..... *casseli*

B. Apical system decidedly eccentric posteriorly; petals not raised

a. Margin thin; petals usually narrowly open at end; anterior odd petal very broad; test usually wider than long

b. Apical system very eccentric; posterior petals diverging and forming nearly a straight line ..... *ashleyi*

bb. Apical system less eccentric; posterior petals diverging and forming a decidedly obtuse angle ..... *ashleyi ynezensis*

aa. Margin moderately thick; posterior petals widely open at end; anterior odd petal not exceptionally broader than the others; test often as long as wide or longer and usually not exceeding 45 mm. in length ..... *gibbsii humilis*

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(103) Raup, D. M., "Dendraster: A Problem in Echinoid Taxonomy," Jour. Paleo., Vol. 30, No. 3, pp. 685-694, figs. 1-4, May, 1956.

(104) Goodwin, T. W., and Fox, D. L., "Some Observations on Pigments of the Pacific Sand Dollars, *Dendraster excentricus* and *Dentraster* [*Dendraster*] *laevis*," Experimentia, Vol. 11, No. 7, pp. 270-276, 1955. See also Univ. Calif. Scripps Inst. Oceanogr., Contrib. for 1955, New Ser., No. 773, pp. 353-359, figs. 1-4, July, 1957.

Dendraster ashleyi Arnold

Plate 21, Figures 1-3, 6; Plate 22, Figures 1, 3; Plate 26, Figure 9

Echinarachnius ashleyi Merriam, Arnold, U. S. Geol. Surv., Bull. 322, p. 58, pl. 24, figs. 6, 7, 1907.

Scutella ashleyi Arnold, J. P. Smith, Calif. State Mining Bureau, Bull. No. 72, p. 38, 1916. "San Diego and lower Fernando formations of the coastal region of southern California."

Dendraster ashleyi Arnold, Hertlein, Stanford Univ. Bull., Ser. 5, No. 78, pp. 84, 85, 1929. "San Diego Pliocene."—Grant and Hertlein, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 2, p. 80, pl. 11, fig. 1; pl. 22, fig. 5 (reproduction of original figure); pl. 30, fig. 4, 1938. "1½ kilometers west of Cockatoo Grove, and about 7 kilometers east of Chula Vista"; "north and also west side of Chollas Valley"; "east of Balboa Park, San Diego."—Hertlein and Grant, Mem. San Diego Soc. Nat. Hist., Vol. 2, Pt. 1, p. 59, 1944. "Just west of Cockatoo Grove," Pliocene.—Woodring, U.S. Geol. Surv., Prof. Paper No. 222, pp. 104, 106, 1950. "San Diego district. Inland localities." "San Diego formation."—Hertlein and Grant, Calif. State Div. Mines, Bull. 170, chapter 2, p. 60, 1954 (1955). "San Diego formation."

TYPE SPECIMEN: No. 165,259, United States National Museum.

TYPE LOCALITY: "Graciosa Ridge, near Orcutt," California, "Fernando (Pliocene)." ["Graciosa member of the Careaga on Graciosa Ridge" (Woodring, 1950, p. 68).]

RANGE: Middle Pliocene in central and southern California and northern Lower California.

OCCURRENCE IN THE SAN DIEGO FORMATION: San Diego (J. P. Smith; Hertlein and Grant; Woodring); north and west sides of Las Chollas Valley, San Diego; and east of Balboa Park, San Diego (Grant and Hertlein). CALIFORNIA ACADEMY OF SCIENCES: Loc. 1175, 1½ kilometers west of Cockatoo Grove and about 7 kilometers east of Chula Vista; (cf.) Loc. 1405, street cut 0.2 mile southwest of Alamo Drive and Center Street, east San Diego; Loc. 28883, 0.4 mile north of Broadway extension (Federal Avenue) on Fairmount (47th Street) (form approaching *ynezensis*); Loc. 28884, embankment on Windsor Drive where Tourmaline Street would intersect if projected; Loc. 28890, 0.4 mile north of Broadway on Fairmount Avenue. LOS ANGELES COUNTY MUSEUM: Loc. 106, back of house 3030 on west side of Reynard Way, San Diego; Loc. 296, street cut on northwest side of Fairmount extension, 0.4 mile north of intersection with Broadway, on west side of Las Chollas Valley, San Diego [approximately same as Loc. 28883 (CAS)]; Loc. 306, on east side of Euclid Avenue, between Federal Boulevard and intersection of Euclid and Home avenues, San Diego; Loc. 311B, about 15 feet above base of bluff on recent road cut at Loc. 311A, on Windsor Drive; east gate of Navy Hospital, San Diego; above barnacle bed, at southwest corner of intersection of Home and Fairmount avenues, San Diego; east side of 2400 block on Euclid Avenue, San Diego.

This species was first illustrated and named, without description, by Arnold. The first formal description of a typical specimen was given by Kew (Univ. Calif. Publ. Bull. Dept. Geol., Vol. 12, No. 2, pp. 115-116, September 28, 1920) as follows:

DESCRIPTION: Test of medium size. Measurements of specimen No. 11043 [Univ. Calif. Coll.]: anteroposterior diameter 62.5 mm., transverse diameter 74 mm., greatest height 6 mm. Markedly thin. Marginal outline subquadrate, the posterior margin being broadly truncated; transverse diameter the greater, with its greatest width in the posterior portion of the test. Upper surface rises gently to the summit, which is posterior to the center of the test and in front of the apical system; greatest elevation within the radius of the length of the petals. Apical system situated far back near the posterior margin. Madreporite pentagonal in outline, with four genital pores opposite the four anterior corners. Lateral petals not symmetrical, the anterior rows of pores in each petal being curved to a greater degree than those of the posterior rows. Petals of the bivium relatively short, and diverging so as to form with their axes an angle of nearly 180 degrees. Poriferous areas comparatively wide, each being about one-half the width of the interporiferous area. Petals of the trivium of the same length; lateral ones somewhat narrower than the odd anterior one. Poriferous areas of the anterior lateral petals equal to about one-half to one-third the width of the interporiferous area; poriferous areas of the odd petal exceedingly narrow, each being about one-eighth the width of the interporiferous area. Inferior surface very slightly concave to the peristome. The latter is small and round. Dichotomously branching ambulacral furrows extend in well marked lines from the peristome to the margin, but become less distinct toward their extremities, especially those of the odd anterior set. Periproct small, subcircular, inframarginal, and placed about twice its own diameter from the edge of the test. Fine tubercles entirely cover the test. The test of this species is relatively more elevated in the younger than the older specimens. (Kew.)

REMARKS: Typical specimens of *Dendraster ashleyi* differ from *D. gibbsii* and other species of the genus *Dendraster,* by their very thin margins, the very broad curvature of the posterior margin, the very eccentric apical system, and the divergence of the petals of the bivium to form nearly a straight line. This latter feature is not so pronounced on Arnold's figure of the type specimen as in most specimens. The odd anterior petal (III) is usually wider than the others, and all the petals are usually only narrowly open at the ends.

This species occurs in the San Diego formation at several localities in the San Diego area. A specimen from Loc. 1175 (CAS), 1½ kilometers west of Cockatoo Grove and about 7 kilometers east of Chula Vista, is definitely referable to *Dendraster ashleyi,* as are a number of specimens collected by G. P. Kanakoff and J. F. Arndt at various localities in the San Diego area. One such specimen collected by Arndt on Euclid Avenue measures 66 mm. in anteroposterior diameter, 72.8 mm. in transverse diameter.

Kew suggested that *Dendraster ashleyi* probably is a descendent of *D. gibbsii;* but Woodring (1950, p. 103) stated that, despite the very eccentric apical system, the thin test suggests closer relationship to *D. coalingaensis* Twitchell[105].

Durham (1955, p. 157) pointed out that two separate lineages appear at about the same time at the base of the Pliocene. These are represented by *Dendraster gibbsii,* with thick margins and an inframarginal periproct, and *D. elsmerensis* Durham[106] with thin margins and a marginal periproct.

Some specimens of *Dendraster ashleyi* bear a general resemblance to *D. pentagonalis* Israelsky[107], which was described from beds of Pliocene age on Cedros Island, Lower California; but they differ from that species in the thinner margins, the generally more eccentric apical system, the large size of the odd anterior ambulacral petal, and the usually less decidedly pentagonal outline of the test.

According to Woodring, *Dendraster ashleyi* is abundant in the Graciosa member of the Careaga sandstone in the Santa Maria district of southern California. Dibblee[108] reported finding it more abundant in the lower Careaga sandstone in Santa Barbara County in the district where he studied the geology.

In addition to its occurrence in western San Diego County and in Santa Barbara County, *Dendraster ashleyi* has been recorded from Pliocene strata in California in the Sargent oil field in Santa Clara County and also in San Benito County; it also is reported at Turtle Bay and on terraces east of San Quintin, Lower California, Mexico.

Dendraster ashleyi ynezensis Kew

Plate 21, Figures 4, 5; Plate 22, Figures 2, 4, 6, 8; Plate 26, Figure 7

Dendraster ashleyi var. *inezanus* Kew (Ms), Kew, Univ. Calif. Publ. Bull. Dept. Geol., Vol. 12, No. 1, p. 15, November 20, 1919. From a soft tan and gray sandstone on the north side of the Santa Ynez River, Fernando formation, Pliocene. [No description or figure.]

Dendraster ashleyi ynezensis Kew, Univ. Calif. Publ. Bull. Dept. Geol., Vol. 12, No. 2, p. 116, pl. 36, figs. 2a, 2b, September 28, 1920. Santa Ynez River district, Santa Barbara County, California. Upper Fernando formation, upper Pliocene.—Grant and Hertlein, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 2, p. 81, pl. 9, fig. 7, 1938. Various localities in San Diego region.—Hertlein and Grant, Mem. San Diego Soc. Nat. Hist., Vol. 2, Pt. 1, p. 59, 1944. "Chula Vista district," Pliocene.—Hertlein and Grant, Calif. State Div. Mines Bull. 170, chapter 2, p. 60, 1954 (1955). "San Diego formation."

TYPE SPECIMEN: No. 11334, Invertebrate Paleontology Collection, University of California.

TYPE LOCALITY: "Santa Ynez River district, Santa Barbara County, California, Univ. Calif. Loc. 3128." "Upper Fernando formation, Upper Pliocene." [According to Woodring (1950, p. 68), the type apparently came from the "upper Santa Ynez Valley in strata presumably of Careaga age."]

RANGE: Middle Pliocene in southern California.

OCCURRENCE IN THE SAN DIEGO FORMATION: Soledad Mountain; Swift Canyon near Boundary Street; Las Chollas Valley above Market Street Bridge; "cf." from road cuts on Alamo Drive and Center Street, north side of upper Las Chollas Valley; off Cherokee Street, on the right side of canyon in old railway embankment; near corner of Thirty-fifth Street and Market Street extension, San Diego (all cited by Grant and Hertlein). CALIFORNIA ACADEMY OF SCIENCES: Loc. 1177, road cut on west side of hill just east of corner of Haines Street and Tourmaline Street, Pacific Beach district; Loc. 1543, ¼ mile east of Fairmount Avenue, in bottom of canyon just south of Laurel Street; Loc. 28884, embankment on Windsor Drive, where Tourmaline Street would intersect if projected, Pacific Beach; Loc. 33218, near Maple and Haller streets, San Diego; Loc. 36384, about two feet

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(105) *Dendraster coalingaensis* Twitchell in Clark and Twitchell, U.S. Geol. Surv., Monogr. 54, p. 196, pl. 90, figs. 2a-c, 1915. Upper portion of Etchegoin formation, Pliocene. See also Stewart, R. B., in Woodring, Stewart, and Richards, U.S. Geol. Surv., Prof. Paper 195, p. 81, pl. 10, figs. 6-9, 10, 11, 12; pl. 39, fig. 7 ("cf."); pl. 45, figs. 1, 2, 3, 4 (var.), 1941.

(106) *Dendraster elsmerensis* Durham, Amer. Jour. Sci., Vol. 247, p. 50, fig. 2F, pl. 1, figs. 2, 3, 4, 6, January, 1949. From "Loc. A4457—apparently in SW¼ of NE¼ of Sec. 8, T 3N, R 15W, San Bernardino Base and Meridian. From hillside on northwest side of stream, about 200 yards upstream from point where contact of Pico formation and basement cross the stream. Collected from 0′ to 25′ above base of Pico formation. In association with numerous molluscs and *Astrodapsis fernandocnsis* Pack."

(107) *Dendraster pentagonalis* Israelsky, Univ. Calif. Publ. Bull. Dept. Geol. Sci., Vol. 14, No. 11, p. 380, pl. 69, figs. 3, 4a, 4b, November 7, 1923. "Cedros Island, Baja California." "Pliocene."

(108) Dibblee, T., Calif. State Div. Mines, Bull. 150, p. 46, 1950.

above conglomerate at base of San Diego formation in road cut on east side of Cabrillo Freeway nearly opposite Mercy Hospital; not localized (No. 181, Chas. Sternberg coll.). LOS ANGELES COUNTY MUSEUM: Loc. 106, behind house 3030, west side of Reynard Way, San Diego; Loc. 107, 100-foot bluff with scattered fossiliferous concretions in clay quarry at end of Arroyo Drive, San Diego; Loc. 123, bluff 100 yards east of Market Street at level of 34th Street (which does not go through at this point); Loc. 127, shell stratum 5 feet thick, Market Street extension in Encanto, 1¼ miles south of Euclid Avenue, San Diego; Loc. 176, at south end of Juniper Street, at crossing of 31st Street, turn right on dirt road leading to Wabash Canyon, on both sides of canyon; Loc. 294, silt back of house No. 3550 Dove Street, San Diego; Loc. 301, exposure of San Diego formation silt, 50 feet long and 10 to 15 feet high, inside east gate of Naval Hospital 4 feet above road (which is parallel to fence), 200 yards west from lowest part of Florida Street, below Balboa Park, San Diego; Loc. 307, near west end of Hayes Avenue if projected to near road under bridge; Loc. 311B, about 15 feet above base of bluff on recent road cut at Loc. 311A, on Windsor Drive, Pacific Beach district; Loc. A-2862, "Near San Diego"; east side of 2400 block on Euclid Avenue, San Diego (J. F. Arndt, coll.); southwest corner of Fairmount and Home avenues, above barnacle bed, also one specimen from barnacle bed, San Diego. SAN DIEGO SOCIETY OF NATURAL HISTORY: Loc. 23, road cut on west side of hill just east of corner of Haines Street and Tourmaline Street, Pacific Beach district; Loc. 80, south slope of Soledad Mountain, first arroyo west of Rose Canyon highway; Loc. 80A, just west of Loc. 80. Also numerous other localities in and near San Diego.

ORIGINAL DESCRIPTION: This is very closely allied to *Dendraster ashleyi* (Arnold) because of its wide odd anterior ambulacral petal and great angular divergence of the petals of bivium, but differs in that the apical system is less eccentric, and in that the test has a more nearly elliptical outline, the transverse diameter being the greater. Its size is usually larger than that of *D. ashleyi.* (Kew.) [The illustration of the type is indicated as approximately natural size and measures approximately 71 mm. in length, 85 mm. in width, 6.5 mm. in height.]

REMARKS: The less eccentric apical system and less divergent angle of the bivium can usually be relied upon to separate this subspecies from typical *D. ashleyi.* This subspecies often attains a very large size; one specimen from Las Chollas Valley above Market Street bridge, San Diego, measures 100 mm. in length, 115 mm. in width, and about 9.5 mm. in height.

This subspecies occurs abundantly in the San Diego formation at various localities and is the echinoid most commonly found in Pliocene beds in the San Diego area.

Through the courtesy of Mr. George P. Kanakoff of the Los Angeles County Museum, we have had the privilege of examining about 75 specimens of this subspecies collected from Pliocene beds in and near San Diego. These reveal that there is considerable variation in size of test, in degree of eccentricity of the apical system, and in size of angle of the bivium. Some of these specimens closely resemble the form illustrated as *D. ashleyi* by Woodring (1950, pl. 20, fig. 1), who remarked that they closely approached the subspecies *ynezensis.*

A series of 17 specimens of *Dendraster* was collected by Kanakoff at Loc. 106 (LAM), on the west side of Reynard Way in San Diego. Seven of these are referable to *D. ashleyi* and 10 to the subspecies *ynezensis.* The average measurements of these were as follows: for *D. ashleyi,* length 54.5 mm., width 68.2 mm., distance of apical system from posterior end 12.8 mm.; for *D. ashleyi ynezensis,* length 58 mm., width 63.1 mm., distance of apical system from posterior end 16.4 mm.

One specimen, 77.5 mm. in length and 86.5 mm. in width, from Loc. 107 (LAM), still retains many of the spines, especially on the oral side. These spines are about 2.6 to 3 mm. in length. They are somewhat greater in diameter and a little longer than those of the Recent *D. excentricus.*

Four specimens from Loc. 294 (LAM) have very thin margins. The apical system is similar to that of the present subspecies. One small specimen (pl. 22, fig. 2) from this locality has a rounded outline (length 20.5 mm., width 20.6 mm.) and an eccentric apical system as in large forms of *D. ashleyi ynezensis.*

A large specimen, typical of this subspecies, collected by Kanakoff from a bluff east of Market Street (at level of 34th Street), measures 81 mm. in length, 92 mm. in width, approximately 10 mm. in height (convexity), with the apical system approximately 22.4 mm. from the posterior margin.

Several specimens of this subspecies, furnished us by E. Dean Milow, were collected about two feet above the conglomerate at the base of the San Diego formation in a road cut on the east side of the Cabrillo Freeway nearly opposite Mercy Hospital.

Some specimens from the San Diego area are intermediate between *Dendraster ashleyi* and the subspecies *ynezensis* and could perhaps be referred to either of these forms. However, most specimens fall into one category or the other.

Dendraster casseli Grant and Hertlein

Plate 22, Figure 7

Dendraster casseli Grant and Hertlein, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 2, p. 81, pl. 1, figs. 1-3; pl. 30, fig. 3, April 19, 1938.

TYPE SPECIMEN: No. 6193, Type Collection, Department of Paleontology, University of California at Los Angeles.

TYPE LOCALITY: "from Loc. 356 (U.C.L.A.), at head of ravine in SE. corner of Sec. 10, T.4N., R.17W., S.B.B. & M., about 0.2 mi. N. of corner, in the *Dendraster* bed, elevation 1300 feet by contour (U. S. Geol. Surv. topog. map of Santa Susana quadrangle)." Los Angeles County, California. "Upper half of the Pliocene."

RANGE: Middle Pliocene in southern California and San José Island, Gulf of California, Lower California, Mexico.

OCCURRENCE IN THE SAN DIEGO FORMATION: LOS ANGELES COUNTY MUSEUM: Loc. 107, 100-foot bluff with scattered concretions in clay quarry at end of Arroyo Drive, San Diego.

ORIGINAL DESCRIPTION: Test of medium size; outline subcircular, the posterior margin more broadly curved, also slightly more broadly curved at distal ends of the anterior paired ambulacra; margin thin but dorsal (abactinal) surface inflated, ventral (actinal) surface slightly concave; apical system slightly excentric posteriorly, and slightly posterior to the highest portion of test, genital pores 4; ambulacra subpetaloid, narrow, long, the poriferous zones gradually becoming obsolete distally, the nonporiferous zones raised, sometimes conspicuously, sometimes the entire ambulacra raised, especially the proximal portion; bivial angle but slightly larger than angles between ambulacra of the trivium; pore-pairs conjugate; primary tubercles imperforate, in depressed scrobicules; ambulacral furrows but slightly depressed but variable, bifurcating close to the peristome; periproct small, nearly circular, on actinal surface close to margin. Length of holotype, 50.7 mm.; width, 51.1 mm.; height, approximately 8.4 mm. (Grant and Hertlein.)

REMARKS: The test of *Dendraster casseli* is characterized by its slightly eccentric apical system and by its long, narrow, open, and raised ambulacral petals.

Two specimens of this species, their actinal surfaces cemented together by matrix, were collected by G. P. Kanakoff at Loc. 107 (LAM), at the end of Arroyo Drive in San Diego. The larger of these measures 56.9 mm. in length, 60.8 mm. in width. The specimens compare favorably with the type specimen of *D. casseli,* differing chiefly in that petals I, II, IV, and V are somewhat more contracted at their distal ends. The difference, however, is believed to be individual variation or perhaps a feature concomitant with the larger size of the specimen.

This is the first record of the occurrence of this species in the San Diego formation. It also is known to occur in the upper half of the Pliocene section in northern Los Angeles County and in Pliocene strata on San José Island in the Gulf of California.

Dendraster gibbsii humilis Kew

Plate 22, Figures 5, 9

Dendraster gibbsii humilis Kew, Univ. Calif. Publ. Dept. Geol., Vol. 12, No. 2, p. 124, pl. 25, figs. 3a, 3b, September 28, 1920. "Coalinga district, Fresno County, California . . . and Santa Maria district, California."—Grant and Hertlein, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 2, p. 88, pl. 1, fig. 4, 1938. Also "Pacific Beach, San Diego, California."

TYPE SPECIMEN: No. 11379, Invertebrate Paleontology Collection, University of California.

TYPE LOCALITY: "Coalinga district, Fresno County, California, Univ. Calif. Loc. 2100." [From "a locality in the Jacalitos Hills west of the Kettleman Hills" according to Stewart, 1941, p. 80.]

RANGE: Middle Pliocene in southern California and northern Lower California.

OCCURRENCE IN THE SAN DIEGO FORMATION: CALIFORNIA ACADEMY OF SCIENCES: Loc. 12164, Pacific Beach (Grant and Hertlein).

ORIGINAL DESCRIPTION: This seems to be an intermediate form between *Dendraster gibbsii* (Rémond) and *D. ashleyi* (Arnold), differing from the former in having a thinner test with angulated margins; from the latter it differs in that the odd anterior petal is narrower, about the same width as the anterior lateral pair, and in that the apical system is less eccentric. (Kew.)

REMARKS: There is little to be added to the above description. Typical specimens differ from *Dendraster gibbsii*[109] in particulars which justify a subspecific name for this form.

This subspecies is known from Pliocene strata at Pacific Beach, San Diego, by two specimens collected by Henry Hemphill. The apical system of these is not so eccentric as that of the type illustrated by Kew; but the general outline of the test, the petals that are widely open at the end, and the similarity in size of the odd anterior petal to the others, all are characters that lead us to refer these specimens to *D. gibbsii humilis.*

In addition to its occurrence in Pliocene beds at San Diego, this subspecies has been recorded as occurring in Pliocene strata in the Coalinga district, the Santa Maria district, and the Purisima formation in California, and at Cedros Island, at Turtle Bay, and near Scammon Lagoon, Lower California, Mexico.

Genus MERRIAMASTER Lambert

Merriamaster Lambert, Rev. Crit. Paléozool., Quinzième année [Vol. 15], No. 1, p. 64, January, 1911. "Type" of the genus: "*Scutella Perrini* Weawer [Weaver]."—Lambert and Thiéry, Essai Nomencl. Raison. Echinid., Fasc. 4, p. 312, 1914, and Fasc. 9, p. 581, 1925.—Grant and Hertlein, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 2, p. 64, 1938. "Type of the genus (by original designation and by monotypy): *Scutella perrini* Weaver."—Mortensen, Monogr. Echin. IV.2. Clypeastroida, p. 396, December 30, 1948. "Genotype: *Merriamaster Perrini* (Weaver)."—Durham, Univ. Calif. Publ. Geol. Sci., Vol. 31, No. 4, p. 161, 1955. "Type species: of *Merriamaster, Scutella perrini* Weaver, orig. desig."

Orchoporus Lambert and Thiéry, Essai Nomencl. Raison, Echinid., Fasc. 4, p. 293, March, 1914. Type by monotypy, sole species, *Orchoporus koehleri* Lambert and Thiéry. (New name for *Astrodapsis* sp. indet., Arnold, U.S. Geol. Surv., Bull. 396, p. 162, pl. 28, figs. 5, 5a, 1909. "Upper Etchegoin formation." (P. 37) From Loc. 4708 "On 1,245-foot hill 4 miles southeast of northwest end of Kettleman Hills, east side of sec. 32, T. 21S., R.17E. *Arca* bed in upper *Mya* zone, or uppermost beds.") (See also Stewart, in Woodring, Stewart, and Richards, 1941, p. 82.)

?*Twitchellia* Lambert, Rev. Crit. de Paléozool., Vol. 20, No. 4, p. 171, 1916. ". . . avec deux espèces, *T. Merriami* Anderson (*Astrodapsis*), type du genre (fig. 7) et *T. Packi*, à pétales courts, l'impair plus ouvert que les autres (fig. 8)." The figures referred to are by W. B. Clark and Twitchell, U.S. Geol. Surv., Monogr. 54, pl. 85, 1915. Type of the genus (by original designation, as above): *Scutella* (?) *merriami* (Anderson) of W. B. Clark and Twitchell, fig. 7 only. Not *Astrodapsis merriami* Anderson, Proc. Calif. Acad. Sci., Ser. 3, Geol., Vol. 2, pp. 193-194, pl. 14, figs. 33, 34, December 4, 1905.

TYPE SPECIES (by original designation): *Scutella perrini* Weaver. Reference given to Arnold and R. Anderson, U. S. Geol. Surv., Bull. 398, pl. 50, figs. 1 and 2, 1910. From Loc. 4712 "east of Zapato Creek, one-half mile south of Adolph Kreyenhagen's house, SW. ¼ SE. ¼ sec. 8, T.22S., R.16E. Variable pebbly sand, with many fossils. *Pecten coalingaensis* zone, or upper middle beds." Upper Miocene or lower Pliocene. [Pliocene]. [*Scutella perrini* Weaver, Univ. Calif. Publ., Bull. Dept. Geol., Vol. 5, No. 17, p. 273, pl. 12, fig. 2, December 28, 1908. Type locality, "In beds presumably of Miocene age near Coalinga, California." [Late Pliocene.] —Grant and Hertlein, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 2, p. 68, pl. 15, fig. 11; pl. 30, fig. 9, 1938. —Stewart in Woodring, Stewart, and Richards, U. S. Geol. Surv., Prof. Paper 195, p. 81, pl. 46, figs. 1, 2, 4, 7, 10, 12, 1941. *Pecten* and *Trachycardium* zone in Kettleman Hills, San Joaquin County, California. San Joaquin formation, late Pliocene. —Durham, Univ. Calif. Publ. Geol. Sci., Vol. 31, No. 4, p. 161, figs. 4f (p. 79), 35c (p. 161), 1955.]

RANGE: Middle Pliocene of California and northern Lower California.

DESCRIPTION: Test ovate, moderately flattened, moderately thick, the margins rounded; genital pores 4 (none between petals I and V); apical system slightly eccentric posteriorly; ambulacral petals open and extending to the margin, usually slightly raised; test with large, well-developed tubercles; ambulacral food grooves on adults bifurcate about one-third the distance from the peristome to the margin; periproct just inframarginal, often on a slight rostrum; internal radial supports simple, moderately developed; internal concentric supports only slightly developed.

REMARKS: A discussion of this genus was given by the present authors in 1938, and recently Durham gave an extensive discussion of its morphology. Stewart pointed out that the type of *Orchoporus*

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(109) *Scutella gibbsii* Rémond, Proc. Calif. Acad. Nat. Sci., Vol. 3, p. 13, April, 1863. "Kern Lake, Buena Vista County." Gabb cited as considering the species to be of Miocene age. See also Grant and Hertlein, 1938, p. 88, pl. 14, fig. 6, 1938. Earlier records cited. Also Stewart, in Woodring, Stewart, and Richards, U.S. Geol. Surv., Prof. Paper 195, p. 80, pl. 40, figs. 2-4; pl. 42, figs. 1-5; pl. 43, figs. 1, 2, 4, 5; pl. 44, fig. 6, 1941.

The recorded occurrence of this species at Lituya Bay, Alaska, by Dall (in Mertie, U.S. Geol. Surv., Bull. 836, p. 130, 1931) is referable to a different species, as indicated by Stewart, 1941, p. 109, footnote 32. It has recently been named *Echinarachnius alaskense* by Durham (Jour. Paleo., Vol. 31, No. 3, p. 628, pl. 72, figs. 6, 8, May, 1957.)

is a young specimen of *Merriamaster perrini,* and although the original figure is said to be deceiving, it appears probable that *Twitchellia* likewise can be referred to *Merriamaster.*

Durham (1955) placed *Merriamaster* in the Dendrasteridae and *Astrodapsis* in the Echinarachniidae. However, *Merriamaster* appears to be more closely related to *Astrodapsis* than to *Dendraster.* Mortensen (1948, p. 397) mentioned that *Merriamaster* may probably represent a transition between *Astrodapsis* and *Dendraster,* but he also added that "in some cases of the very numerous species of this group from the American west coast it may be questionable to which of the three said genera they should be referred."

The test of *Merriamaster* differs from that of *Astrodapsis*[110] in the slightly eccentric apical system, in the somewhat shorter and generally less elevated petals, and in the bifurcation of the food grooves about one-third the distance from the peristome to the margin. In *Astrodapsis* the apical system is central, the petals are decidedly raised above the surface, and the central food grooves extend unbranched to the margin.

Merriamaster differs from *Dendraster* in the less eccentric apical system, the more open and usually raised petals, the thicker and more rounded margins, the fewer interior concentric supports, the greater number of plates on the oral surface, and the usually larger spine bases.

Only five or possibly six species in California and Lower California appear to be referable to the genus *Merriamaster.* Two of these occur in Pliocene beds in the San Diego area. In the San Joaquin Valley this genus is known to occur only in the San Joaquin formation of late Pliocene age. The genus *Merriamaster* is not definitely known to occur in western North America north of Half-moon Bay, California.

KEY TO THE SPECIES OF MERRIAMASTER

A. Outline subpentagonal; petals rather narrow and decidedly elevated at and near apex; shallow interambulacral depressions present on abactinal surface; tubercles rather small.....*pacificus*

B. Outline broadly oval; petals moderately broad and only slightly elevated; interambulacral depressions on abactinal surface only slightly developed; tubercles large.....*israelskyi*

Merriamaster cf. **M. israelskyi** E. K. Jordan and Hertlein

Plate 23, Figures 10, 12, 14

The original reference to typical *M. israelskyi* is Proc. Calif. Acad. Sci., Ser. 4, Vol. 15, No. 14, p. 424, pl. 27, figs. 4, 6, July 22, 1926.

Astrodapsis israelskyi E. K. Jordan and Hertlein, Grant and Hertlein, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 2, p. 73, 1938. "lower beds in the Pliocene at Pacific Beach, San Diego"; "Cabrillo Canyon, Balboa Park, San Diego."

TYPE SPECIMEN: No. 2086, Type Collection, Department of Geology, California Academy of Sciences.

TYPE LOCALITY: "Bernstein's abalone camp, Cedros Island, Lower California; upper Pliocene."

RANGE: Middle Pliocene in southern California, and Cedros Island and Turtle Bay, Lower California, Mexico.

OCCURRENCE IN THE SAN DIEGO FORMATION: LOS ANGELES COUNTY MUSEUM: (cf.) Loc. 107, 100-foot bluff with scattered fossiliferous concretions in clay quarry at end of Arroyo Drive, San Diego; Loc. 122, 20 to 30 feet below end of Loring Street, Pacific Beach; Loc. 124, 15 feet below floor level of Snyder Continuation school, San Diego. SAN DIEGO SOCIETY OF NATURAL HISTORY: Cabrillo Canyon, Balboa Park, San Diego.

ORIGINAL DESCRIPTION of *A. israelskyi*: Test small; subcircular to oval in outline, not greatly elevated, the upper surface rather flat; margin thick, evenly rounded and entire; apical system central, or slightly posterior, the apex of the test slightly anterior to the center of the madreporic area; madreporic area pentagonal, with four genital pores; petals narrow, slightly elevated, widely open, and extending nearly to the margin; rows of pores at first diverge, then at about half the distance to the margin they

(110) *Astrodapsis* Conrad, Proc. Acad. Nat. Sci. Philadelphia, Vol. 8, No. 6, p. 315, apparently issued approximately April 25, 1957. Only species cited, *Astrodapsis antiselli* Conrad. "Monterey Co., Cal." Middle Tertiary. Illustrated by Conrad, U.S. Pac. R.R. Repts., Vol. 7, Palaeo., p. 196, pl. 10, figs. 1, 2, 1857. *"Estrella"* [Monterey County], California.—Richards, Trans. San Diego Soc. Nat. Hist., Vol. 8, No. 9, pl. 7, figs. 1a, 1b, 1935. (Type specimen illustrated).—Grant and Hertlein, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 2, p. 70, pl. 16, figs. 3, 4, 1938.—Durham, Univ. Calif. Publ. Geol. Sci., Vol. 31, No. 4, pp. 104, 167, fig. 3d (p. 78), fig. 22a (p. 105), 1955.

converge slightly, after which they continue toward the margin parallel or very slightly divergent; outer row of pores more pronouncedly sinuous than inner; interambulacral areas relatively broad, little depressed, flat, sloping gently from the apex toward the margin; inferior surface concave toward the center; mouth central, large, subpentagonal in outline; ambulacral furrows not distinct, but branching close to their origin at the peristome and extending nearly to the margin; periproct fairly large, situated on ventral surface and a little less than its own diameter from the margin; tuberculation prominent, the tubercles rather large and distantly spaced, those on the inferior surface perhaps even more prominent than those above. Anteroposterior diameter 37.5 mm.; transverse diameter 35.3 mm.; greatest elevation 7.9 mm. (E. K. Jordan and Hertlein, Proc. Calif. Acad. Sci., Ser. 4, Vol. 15, No. 14, p. 424, pl. 27, figs. 4, 6, July 22, 1926.)

REMARKS: The authors of this species recognized its general relationship to *"Dendraster" perrini*, the type species of *Merriamaster*. Study of a series of specimens of *"Astrodapsis" israelskyi* leads the present authors to place it in the genus *Merriamaster*. This assignment is based upon the slight eccentricity of the apical system and especially on the fact that the central food grooves on the oral surface of the test do not extend to the margin but branch about a third the distance from the peristome to the margin. Assuming that bifurcation of the food grooves is a generic character of *Merriamaster*, *Astrodapsis kewi* E. K. Jordan and Hertlein[111] also belongs in *Merriamaster*.

The specimens from San Diego referred to *Merriamaster* cf. *M. israelskyi* range in length from about 25 mm. to 43.3 mm. None of these are perfectly preserved; but in observable characters these specimens agree in general with the type of this species, and they closely resemble specimens from San Bartolomé Bay (Turtle Bay), Lower California.

In two specimens from Balboa Park in the collection of the San Diego Society of Natural History, the larger one 43.3 mm. long and 43.4 mm. wide, the actinal surface is moderately well exposed. In outline of test, character of tubercles, and thickness of margin, these specimens are similar to *M. israelskyi*.

Four imperfect and about a dozen smaller and quite imperfect specimens of *Merriamaster* were collected by George Kanakoff at Loc. 124 (LAM), with specimens of *M.* cf. *M. israelskyi*. The greatest diameter measurable among these is 71.8 mm. The outline, the moderately thick margins, and the tuberculation on the oral surface, where observable, do not differ greatly from those of *M. israelskyi*. The incompleteness and poor preservation of these specimens prevent positive identification. It is possible that some of these might be referable to *M. pacificus*. Specimens from other localities in San Diego, none of them well preserved, appear to be referable to *M.* cf. *M. israelskyi*.

Merriamaster israelskyi differs from *M. pacificus* in the ovate rather than subpentagonal outline of the test, the broader less elevated petals, the coarser tuberculation, the slightly thicker margins, and the very slight development of the interambulacral depressions on the aboral surface.

In an earlier paper we mentioned the possibility that Smith's record of *Astrodapsis fernandoensis* in the "San Diego" region might be referable to *M. israelskyi* or to *M. pacificus*[112].

In *Merriamaster israelskyi* the apical system is almost central in the type specimen and in most others and the margin is moderately thick, whereas in *M. perrini* the apical system is moderately eccentric and the margin is very thick. The ovate outline and much less eccentric apical system separate *M. israelskyi* from *M. arnoldi* Twitchell[113].

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[111] *Astrodapsis kewi* E. K. Jordan and Hertlein, Proc. Calif. Acad. Sci., Ser. 4, Vol. 15, No. 14, p. 425, pl. 27, figs. 2, 3, July 22, 1926. "Bernstein's abalone camp, Cedros Island, Lower California; upper Pliocene."

[112] "Smith (1916, p. 38) recorded the geologic occurrence of *A. fernandoensis* as 'San Diego and Lower Fernando formations of the coastal regions of Southern California' but we have not seen any specimens of this species in any of the collections from the San Diego Pliocene available to us. Possibly Smith's record was based upon imperfect specimens of *Astrodapsis israelskyi* or *Merriamaster pacificus* which have been discovered there since Smith's paper was issued." (Grant and Hertlein, 1938, p. 73, footnote.)

[113] *Dendraster arnoldi* Twitchell, U.S. Geol. Surv., Monogr. 54, pp. 192-193, pl. 88, figs. 4a-d, 1915. "Near A. Kreyenhagen's place and south of Lucille well, 2 miles southwest of Coalinga in Coalinga district, California." "Etchegoin formation." Pliocene.—Stewart in Woodring, Stewart, and Richards, U.S. Geol. Surv., Prof. Paper 195, p. 81, pl. 39, fig. 5; pl. 41, fig. 3; pl. 46, figs. 3, 5, 6, 8, (cf.) 9, 11, (cf.) 13, 1941 (as *Dendraster* (*Merriamaster*) *arnoldi*). According to Stewart, "Kew's *D. coalingaensis* Twitchell is *D.* (*Merriamaster*) *arnoldi* Twitchell."

Merriamaster pacificus Kew

Plate 23, Figures 1-6, 11; Plate 25, Figure 6; Plate 26, Figure 11

Dendraster pacificus Kew, Univ. Calif. Publ. Bull. Dept. Geol., Vol. 12, No. 2, list opp. p. 52, p. 128, pl. 33, figs. 1a-c, September 28, 1920. "Cedros Island, Lower California; Pacific Beach, San Diego County, California." "San Diego formation, Upper Pliocene."—E. K. Jordan and Hertlein, Proc. Calif. Acad. Sci., Ser. 4, Vol. 15, No. 14, p. 420, 1926. "Pliocene of Pacific Beach" (Kew's record.)

Merriamaster pacificus Kew, Grant and Hertlein, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 2, p. 67, pl. 20, fig. 9, 1938. "Pacific Beach, San Diego"; and "Cabrillo Canyon, San Diego."—Hertlein and Grant, Calif. Jour. Mines and Geol., Rept. 35 of State Mineralogist, p. 70, 1939. "Cabrillo Canyon," "San Diego formation," Pliocene.—Hertlein and Grant, Mem. San Diego Soc. Nat. Hist., Vol. 2, p. 59, 1944. "Cabrillo Canyon," San Diego, Pliocene.—Woodring, U.S. Geol. Surv., Prof. Paper 222, p. 104, "Pacific Beach and inland," p. 106, "San Diego district," "San Diego formation," 1950.—Hertlein and Grant, Calif. State Div. Mines, Bull. 170, chapter 2, p. 60, 1954. "San Diego formation."

Dendraster (*Merriamaster*) *pacificus* Kew, Woodring, Stewart, and Richards, U.S. Geol. Surv., Prof. Paper 195, p. 113, 1941. "Pacific Beach."

TYPE SPECIMEN: Holotype[114] No. 448, Type Collection, Department of Geology, California Academy of Sciences.

TYPE LOCALITY: "Pacific Beach, San Diego County, California." "San Diego formation, Upper Pliocene."

RANGE: Middle Pliocene in southern California and northern Lower California.

OCCURRENCE IN THE SAN DIEGO FORMATION: Pacific Beach (Kew; E. K. Jordan and Hertlein; Grant and Hertlein); Cabrillo Canyon, Balboa Park, San Diego; Pacific Beach and inland (Woodring). LOS ANGELES COUNTY MUSEUM: Loc. 122, 20 to 30 feet below end of Loring Street, Pacific Beach; Loc. 308, 0.2 mile north of intersection of Harbor Drive and Tourmaline Street, Pacific Beach; Loc. 309, northwest of Chalcedony Street, gully in second canyon east of Kate Sessions School, Pacific Beach. UNIVERSITY OF CALIFORNIA: Loc. 3069, ¼ mile north of Crystal Road, near top of cliff just below heavy conglomerate bed, Pacific Beach (L. Phillips coll.).

ORIGINAL DESCRIPTION: Test small. Average measurements of holotype: anteroposterior diameter 36 mm., transverse diameter 35 mm., greatest height 8.3 mm. Outline subpentagonal. Upper surface depressed, and rising gently from a moderately thickened and rounded margin to a low apex situated slightly anterior to the center of the test. Very indistinct depressions are present in the interambulacral areas. Apical system slightly eccentric to the posterior. Petals of the trivium of the same length and longer than those of the bivium, extending a little over half the distance from the apical system to the margin. Rows of pores diverge for about one-half the length of the petal and then continue in parallel lines to the end, the outer rows converging but little in the distal portion of the petal; a few sporadic pores extend beyond nearly to the edge of the test. Odd anterior petal is slightly narrower than the lateral petals. Petals are more or less elevated, this being a distinctive character. Four large genital pores and five perforated radial plates are present in the apical system. Lower surface concave to the peristome; the latter is subcircular in outline and posterior to the center of the test, being opposite the apical system. Distinct, broad ambulacral furrows present, branching dichotomously a short distance from the mouth and continuing to the margin. Tuberculation prominent; consists of a few large scrobicular tubercles on the petals; smaller secondary tubercles are present over the remainder of the upper surface, interspaced with numerous milliaries; the under side is covered by a few large tubercles of the same size as on the petals, and interspaced with numerous smaller ones. Periproct round, inframarginal, and situated a distance about equal to its own diameter from the edge of the test. (Kew.)

REMARKS: Diagnostic features of this species are the pentagonal outline, the slightly eccentric apical system, the narrow petals, decidedly raised near the apex, and the shallow interambulacral depressions on the aboral surface.

A series of 14 specimens collected by J. F. Arndt at Loc. 122 (LAM), Pacific Beach, range from 20 to 33.8 mm. in maximum diameter. Most of these are slightly crushed or imperfect; but all have the outline, shape and height of petals, and other characters of *Merriamaster pacificus*. A series of 25 specimens collected by Mr. G. P. Kanakoff at Loc. 308 (LAM), 0.2 mile north of the intersection of Harbor Boulevard and Tourmaline Street, Pacific Beach, range from 18 to 38.6 mm. in maximum diameter. Some of these are quite well preserved and are typical of this species.

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(114) Two "Cotypes" were originally cited: No. 448, Department of Geology Type Collection, California Academy of Sciences, and No. 11340, Invertebrate Paleontology Collection, University of California. Measurements of the "holotype" also were given. These measurements agree with those of the specimen illustrated as "Cotype" No. 448, and therefore it is here selected as the holotype.

Most of the other specimens of this species that we have seen from San Diego, except the holotype, are poorly preserved and furnish no additional information concerning this species.

A specimen in the collections of the San Diego Society of Natural History collected at Pacific Beach by Frank Stephens measures 25.5 mm. in length, 27.4 mm. in width, 7.8 mm. in height. The oral surface is encrusted with sediment, but the position of the apical system and shape of the petals are those of *M. pacificus*. Two specimens from Cabrillo Canyon in San Diego, in the collections of the same institution, are tentatively referred to *M. pacificus* on the basis of their subpentagonal outline and somewhat flattened margins.

A specimen from Loc. 124 (LAM), 15 feet below the floor level of Snyder Continuation School in San Diego, is 35 mm. in diameter. It is imperfectly preserved, but the general outline of the apical system is that of the present species. However, it may be referable to *M.* cf. *M. israelskyi* which occurs at that locality.

So far as is known, *Merriamaster pacificus* is restricted to the San Diego horizon or to beds of approximately that age in southern California and at Cedros Island, Lower California. The record cited by Argamakova[115] of the present species in the Nutovo series, late Pliocene, on Sakhalin Island, Russia, needs confirmation.

Family MELLITIDAE Stefanini

Medium-sized to large, flattened; well-developed internal supports; posterior interambulacral and paired ambulacral lunules or indentations; petals well defined, moderately closed; pores conjugate, outer member of pore-pair elongated, a few primary pore-pairs outside petals; paired interambulacra not in contact with basicoronal plates on oral surface; interambulacra on oral surface widening toward ambitus, about as wide as ambulacra at ambitus; basicoronal plates fairly small, interambulacral plates slightly larger than ambulacral plates; periproct on oral surface between posterior interambulacral lunule and peristome; ambulacral food grooves bifurcating just outside basicoronal plates. (Durham, 1955.) Early Miocene to Recent. Recent along tropical and warm temperate coasts of the Americas.

REMARKS: Two genera, *Encope* L. Agassiz and *Mellita* L. Agassiz, in this family, with 5 marginal lunules or notches, are known from the late Tertiary of California. *Scutaster* Pack, with 3 lunules, formerly included in this family, was recently placed in the family *Scutasteridae* by Durham, 1955.

Genus ENCOPE L. Agassiz

Encope L. Agassiz, Cat. Ectyp. Echin., pp. 6, 17, 1840. Sole species: "*grandis* Ag. . . . (Species viva.) Martinique."—L. Agassiz, Monogr. Echin. Viv. Foss., Seconde Monogr. Scutel., p. 45, 1841.—C. W. Cooke, Jour. Paleo., Vol. 16, No. 1, p. 19, 1942. "Genotype, *Encope grandis* Agassiz."—Mortensen, Monogr. Echin., IV.2. Clypeastroida, p. 433, 1948. "Genotype: *Encope grandis* L. Agassiz."—Durham, Geol. Soc. Amer., Mem. 43, Pt. 2, p. 42, 1950." Genotype: *Encope grandis* Agassiz (monotypic)"—Durham, Univ. Calif. Publ. Geol. Sci., Vol. 31, No. 4, p. 174, November 21, 1955. "Type species: of *Encope, E. grandis* L. Agassiz, monotypic."

Moulinia L. Agassiz, Monogr. Echin., Seconde Monogr. Scutel., pp. 3, 139, 1841. Sole species: "*Moulinia cassidulina* Ag.", pl. 22, figs. 1-6, 1841. From "côtes de la Martinique." [According to A. Agassiz, Mem. Mus. Comp. Zool., Vol. 3, pp. 326-328, 1872, and Mortensen, 1948, p. 435, this is "only a developmental stage of *Encope (emarginata)*"].

Moulinsia L. Agassiz in L. Agassiz and Desor, Ann. Sci. Nat. (Zool.), Ser. 3, Vol. 7, p. 139, 1847. For *Moulinia* L. Agassiz, 1841.

Echinoglyphus Van Phelsum, Gray, Proc. Zool. Soc. London for 1851, p. 37, October 28, 1852. "The *Encope* of Agassiz."

Echinoglycus Van Phelsum, Gray, Cat. Rec. Echin. Brit. Mus., Pt. 1, p. 24, 1855. Several species cited, including *Encope grandis* L. Agassiz.

Not *Echinoglycus* Van Phelsum, L. Agassiz, 1841. Type (designated by Durham, 1955, p. 175): *Echinoglycus irregularis* Leske [=*Echinodiscus bisperforatus* Leske.]

Ravenellia Lütken, Vidensk. Meddel. Nat. For. Kjøbenhavn for 1863, p. 168 (100), 1863. Type by monotypy: *Scutella macrophora* Ravenel.

Not *Ravenelia* McCrady, 1859.

Macrophora Conrad, Proc. Acad. Nat. Sci. Philadelphia, Vol. 17, No. 2, p. 74, 1865. Species cited: "*M. macrophora*, (*Scutella*), Ravenel" and "*M. raveneli*, C." [*Scutella macrophora* Ravenel, type by tautonymy. Described in Proc. Acad. Nat. Sci. Philadelphia, Vol. 1, p. 81, 1841. "found in calcareous deposite upon my plantation on Cooper River, in St. Thomas's Parish, about 17 miles from Charleston." South Carolina. Pliocene.]

Desmoulinaster Lambert and Thiéry, Essai Nomencl. raisonnée Echin., Fasc. 4, p. 294, March, 1914. New name for *Moulinia* L. Agassiz, 1841 "(barbarisme)" and *Moulinsia* L. Agassiz, 1847, (not *Moulinsia* Grateloup, 1840). "Type unique: *D. cassidulinus* Desmoulins (*Scutella*)" . . .

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(115) Argamakova, V. F., Trans. Oil Geol. Inst., Ser. A, Fasc. 41, pp. 27, 41, pl. 1, fig. 6, 1934. On the right side of Great-Uini River, Sakhalin Island, Russia. Nutovo series, late Pliocene.

TYPE SPECIES (by monotypy): "*grandis* Ag. . . . (Species viva.) Martinique." [Described by L. Agassiz, Monogr. Echin., Seconde Monogr. Scutel., p. 57, pl. 6, figs. 1-9, 1841. ". . . provient probablement des Antilles." —A. Agassiz, Illustr. Cat. Mus. Comp. Zool., No. 7 (Mem. Mus. Comp. Zool., Vol 3), Pt. 1, p. 127, 1872; Pt. 3, p. 545, pl. 13d, figs. 5, 6, 1873. Gulf of California. —Mortensen, Monogr. Echin. IV.2. Clypeastroida, p. 437, pl. 63, figs. 1, 2, 1948.]

RANGE: Early Miocene to Recent. Recent in tropical and subtropical waters on the east and west coasts of the Americas, from the intertidal zone to about 130 meters (71 fathoms), but usually in less than 50 meters (27 fathoms).

DESCRIPTION: Test stout, with a posterior interambulacral lunule, and with marginal notches or slits or lunules in two or more of the ambulacra; genital pores 5. (H. L. Clark, 1925.)

REMARKS: This genus is known to occur both living and fossil on the east and west coasts of the Americas. Durham (1950) recorded 13 species and subspecies from Pliocene and Pleistocene strata in the Gulf of California region. It is known to occur in Pleistocene beds at Magdalena Bay, Lower California. The present record of *Encope* in beds of Pliocene age at San Diego is the first record of its occurrence in late Tertiary strata of the coastal region of California. The occurrence of *Encope* has been known for years in the Pliocene beds in Imperial County, California, near the head of the Gulf of California.

Several species and subspecies have been described by A. H. Clark (1946) and H. L. Clark (1948) as occurring in tropical and subtropical waters of the western Americas, abundantly in the Gulf of California and south to northern Peru; but Mortensen (1948) recognized only 8 of these as valid. Dimensions of a large specimen of the genus *Encope* taken at the Galapagos Islands are given by H. L. Clark (1948) as 150 and 155 mm.

Mellita L. Agassiz, which has 4 rather than 5 genital pores, has already been recorded by the present authors (1938, pp. 101-103) from the Temblor beds of middle Miocene age in California and from Pleistocene sediment at San Diego and Newport Beach. J. P. Smith (1919, p. 131) also cited the occurrence of this genus in the Quaternary of southern California, as have several authors subsequently.

Encope tenuis Kew

Plate 23, Figures 7, 13; Plate 24, Figure 11; Plate 25, Figure 4

Encope tenuis Kew, Univ. Calif. Publ. Bull. Dept. Geol., Vol. 8, No. 5, p. 47, pl. 1, fig. 1; pl. 2, fig. 1, April 16, 1914.—Kew, Univ. Calif. Publ. Bull. Dept. Geol. Sci., Vol. 12, No. 2, p. 136, pl. 36, fig. 1; pl. 37, figs. 1a, 1b, September 28, 1920. "Coyote Mountain, Imperial County, California." "Lower Division of the Carrizo Creek beds, Pliocene."

TYPE SPECIMEN: "Cotypes" Numbers 10050 and 10051, Invertebrate Paleontology Collection, University of California.

TYPE LOCALITY: "Lower Division of the Carrizo formation at Coyote Mountain and Carrizo Valley," California. "Pliocene." [Coyote Mountain, only, cited by Kew, 1920.]

RANGE: Middle Pliocene in southern California and in Lower California, Mexico.

OCCURRENCE IN THE SAN DIEGO FORMATION: LOS ANGELES COUNTY MUSEUM: Loc. 107, 100-foot bluff with scattered fossiliferous concretions in clay quarry at end of Arroyo Drive, San Diego. SAN DIEGO SOCIETY OF NATURAL HISTORY: 31st Street and Logan Avenue in San Diego.

ORIGINAL DESCRIPTION: Test broad, transverse diameter sometimes greater than the anteroposterior diameter. Greatest width posterior to the center. Test thin, with sharply angular margin. Summit posterior to apical sysem and immediately anterior to interambulacral lunule or foramen. Area immediately surrounding the lunule somewhat tumid. Ambulacral notches broad, deep, contracting slightly near the margin of the test and tending to close. Both interambulacral lunule and ambulacral notches varying somewhat in size. Apical system central. Petals nearly closed, and reaching about two-thirds the distance to the margin. Petals rather narrow. The two lateral petals of the trivium broader and averaging nine per cent shorter than the others. Interporiferous areas slightly lenticular, and at widest part about same dimensions as the poriferous area. Actinal side flat, and marked by deep ambulacral furrows which branch immediately from the peristome and a second time a short distance from the outer margin. The main furrows are broad, shallow and straight, deepening

as the ambulacral notches are approached. Mouth small and not sunken. Anus situated on the inferior surface slightly anterior to the interambulacral lunule. (Kew.)

Measurements of figured specimens: of No. 10050, anteroposterior diameter, 92.7 mm., transverse diameter, 96.0 mm., greatest thickness, 10.3 mm.; of No. 10051, anteroposterior diameter, 110.9 mm., transverse diameter, 105.8 mm. (Kew.)

REMARKS: Two specimens of this species are represented in collections from the San Diego formation. The larger and more nearly complete specimen was collected by George Kanakoff at Loc. 107 (LAM), at the end of Arroyo Drive, San Diego. It measures 104.5 mm. in anteroposterior diameter, 97 mm. in transverse diameter (incomplete), and 12 mm. in height. One specimen in the collection of the San Diego Society of Natural History was collected by Mrs. L. D. Bonnet, San Diego, at 31st Street and Logan Avenue in that city. This specimen is fairly well preserved, but the margins are mostly incomplete. It is approximately 74 mm. in anteroposterior diameter.

The specimen in the collections of the San Diego Society of Natural History has adhering to it some gray micaceous silty sandstone, typical of the San Diego formation. Adhering to the specimen collected by Kanakoff is a slight amount of yellowish-gray sediment similar to that at the end of Arroyo Drive. It appears, then, that there is no reason to doubt the occurrence of this species in the San Diego formation. This record is in harmony with that of *Lovenia hemphilli,* which also occurs in the San Diego formation and in Pliocene strata in the Gulf of California region.

We compared specimens from San Diego with several specimens from Pliocene beds at Loc. 680 (CAS), Alverson Canyon, Coyote Mountain, Imperial County, California, identified as *Encope tenuis* by Merle C. Israelsky: no essential differences are evident. The test of this species is known to be somewhat variable. The specimens from Imperial County vary in the shape of the interambulacral lunule and in the distance it extends anteriorly beyond the posterior ends of the bivium.

Characteristic of *Encope tenuis* are the very thin margins, the shape of the test, highest posteriorly, and the posterior position of the interambulacral lunule relative to the bivium. The very thin margins and the open ambulacral notches distinguish *Encope tenuis* from the Recent *E. californica* Verrill[116], in which the openings are usually in the form of closed lunules.

Smith[117] mentioned the occurrence of *E. tenuis* in the fauna of "Carrizo (Imperial Co., Calif., and Cerros Island, Lower California, lat. 33°N. —28°N.)." However, this record probably refers only to the occurrence of *E. tenuis* in Imperial County, which he indicated on another page (page 150). Beal[118] mentioned *"Encope* sp. aff. *E. tenuis"* from the Pliocene Salada formation, 1 kilometer north of Rancho Conejo in the La Paz Quadrangle in south central Lower California.

Encope loretoensis Durham[119], described from Pliocene beds at Arroyo de Gua on the east coast of Lower California, was said to differ from *E. tenuis* in that about two-thirds of the interambulacral lunule extends anterior to a line connecting the ends of the bivium. In *E. tenuis,* as mentioned above, the anterior extent of the lunule is quite variable. In view of the variation it appears doubtful whether *E. loretoensis* should be assigned more than subspecific status.

Encope tenuis, E. loretoensis, and *E. californica* are members of a group which apparently is represented in the Caribbean by such forms as *E. michelini* L. Agassiz and *E. emarginata* Leske.

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(116) *Encope californica* Verrill, Amer. Jour. Sci., Ser. 2, Vol. 49, p. 97, January, 1870. "La Paz" and "Cape St. Lucas" in the "Gulf of California." Recent.—Grant and Hertlein, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 2, p. 96, pl. 11, fig. 4; pl. 30, fig. 2, 1938. Pleistocene and Recent.

(117) Smith, J. P., Proc. Calif. Acad. Sci., Ser. 4, Vol. 9, No. 4, pp. 149, 154, 1919.

(118) Beal, C. H., "Reconnaissance of the Geology and Oil Possibilities of Baja California, Mexico," Geol. Soc. Amer., Mem. 31, p. 81, 1948.

(119) *Encope loretoensis* Durham, Geol. Soc. Amer., Mem. 43, Pt. 2, p. 46, pl. 37, fig. 4; pl. 41, figs. 1, 4, 5, August 10, 1950. Loc. A-3552 (UC), an echinoid-pecten bed just above Loc. A 3551, which is, "Lower Pliocene, Arroyo de Gua, north of Loreto, Lower California. On north side of arroyo, about a quarter of a mile below point where road passes over divide into Arroyo de Arce. A 2-foot zone of echinoids interbedded in sandstones and conglomerates."

Order SPATANGOIDA Claus

Family SPATANGIDAE Gray

Peristome transversely elongated; some or all of the ambulacra more or less petaloid, or more or less sunken, or both; subanal fasciole present. (H. L. Clark, 1925.) Paleogene to Recent. (Durham and Melville.)

Genus SPATANGUS Gray

Spatagus O. F. Müller, Prod. Zool. Danicae, p. 236, 1776. Species listed: *S. purpureus* [Müller] and *S. pusillus* [Müller].

Spatangus Klein, Gray, Ann. Philos., Vol. 26, p. 430, 1825. Sole species: "*S. purpureus*, Leske, t.43, f.3,5; t.45,f.5."—Mortensen, Monogr. Echin. V.2. Spatangoida, II, p. 6, December 20, 1951. "Genotype: *Spatangus purpureus* O. Fr. Müller."

Not *Spatangus* Klein, Nat. Dispositio Echin. p. 33, 1734 (pre-Linnaean).

Prospatangus Lambert, Mém. Soc. Géol. France, Paléon., Vol. 9, Fasc. 3, Mém. 24, p. 55, 1902.—Lambert and Thiéry, Essai Nomencl. Raison. Echinid., Fasc. 6, 7, p. 459, December, 1924. "Type: *P. purpureus* Müller (*Spatangus*), vivant des mers d'Europe."

Spatangus O. F. Müller, H. L. Clark, Mem. Mus. Comp. Zool., Vol. 46, No. 2, p. 233, 1917. "Type, *Spatangus purpureus* O. F. Müller, 1776."—Grant and Hertlein, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 2, p. 131, 1938. "Type of the genus (designated by H. L. Clark, . . . 1917): *Spatangus purpureus* O. F. Müller."

TYPE SPECIES (designated by H. L. Clark, Mem. Mus. Comp. Zool., Vol. 46, p. 233, 1917, "Type, *Spatangus purpureus* O. F. Müller, 1776"; and *Spatangus* Gray with the type species, *Spatagus purpureus* O. F. Müller, placed on the Official List of Generic Names in Zoology in Opinion 209 of the International Commission on Zoological Nomenclature, March 8, 1954): *Spatagus purpureus* O. F. Müller [Prod. Zool. Dan., p. 236, 1776. Denmark and adjacent regions. Figured by A. Agassiz, Illustr. Cat. Mus. Comp. Zool. No. 7 (Mem. Mus. Comp. Zool., Vol. 3), Pt. 3, p. 565, pl. 11f, figs. 19-22; pl. 14a, fig. 1; pl. 19c, figs. 5, 6; pl. 26, figs. 24-27; pl. 32, figs. 17, 18; pl. 34, figs. 3, 4; pl. 37, fig. 16; pl. 38, figs. 34, 35, 1873. "Norway; Mediterranean." —Mortensen, Danish Ingolf-Exped., Vol. 4, Pt. 2, Echin. (2), pp. 123-129, pl. 2, figs. 8, 12, 14, 16; pl. 16, figs. 1-2, 5-10, 22, 24-25, 27, 29, 31-32, 34, 1907. North Sea, Faroe Island, etc. See also Mortensen, 1951, pp. 10-14, for synonymy and discussion of this species.]

RANGE: Eocene to Recent. Bathymetric range of Recent species usually from 50 to 1000 meters (27 to 547 fathoms), one species (*S. raschi* Lovén) to a depth of 1472 meters (805 fathoms).

DESCRIPTION: Peripetalous fasciole wanting; sternum well developed, much longer than wide, fully covered with tubercles; at least ten distal pore-pairs developed in anterior series of Petals II and IV; genital pores four. (H. L. Clark, 1925.)

REMARKS: In the eastern Pacific this genus, with heart-shaped test, occurs chiefly in shallow waters of the northern hemisphere; but in the eastern Atlantic it ranges south to the Cape of Good Hope and in the south Pacific to New Zealand, occasionally to a depth of 1472 meters (805 fathoms). Ten Recent species were included in this genus by Mortensen. The only Recent species of western North America, *Spatangus californicus* H. L. Clark, occurs from Cordell Bank, California, to San Francisquito Bay in the Gulf of California at depths ranging from 64 to 412 meters (35 to 225 fathoms). Three species of this genus have been described from the Tertiary of California, *Spatangus pachecoensis* Pack and *S. tapinus* Schenck from strata of Eocene age and *S. rarus* Israelsky from strata of Pliocene age.

Spatangus rarus Israelsky

Plate 25, Figures 1-3

Spatangus rarus Israelsky, Univ. Calif. Publ. Bull. Dept. Geol. Sci., Vol. 14, No. 11, p. 383, pl. 73, figs. 1a-1c, November 7, 1923.—Grant and Hertlein, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 2, p. 132, pl. 10, fig. 6, 1938. "Pliocene. —Pacific Beach, San Diego, California (Israelsky)."

TYPE SPECIMEN: Holotype No. 917, Department of Geology, California Academy of Sciences.

TYPE LOCALITY: "Pacific Beach, San Diego, California." "Pliocene."

RANGE: Known only from the type locality.

OCCURRENCE IN THE SAN DIEGO FORMATION: CALIFORNIA ACADEMY OF SCIENCES: Loc. 547, Pacific Beach (Israelsky; Grant and Hertlein). LOS ANGELES COUNTY MUSEUM: Loc. 122, 20-30 feet below the end of Loring Street, Pacific Beach.

ORIGINAL DESCRIPTION: Marginal outline of the test nearly circular, notched anteriorly, shallowly truncated posteriorly. Abactinal surface somewhat elevated, gently arched, greatest height of test

anterior to the apical system which is subcentral. Petals paired, slightly sunken below general surface of test; pores paired, about 1 mm. apart and zygose. Odd anterior ambulacrum non-petaloid, lying wholly in groove which extends from ambitus to the apical system. Antero-lateral ambulacra petaloid, with petal outlines somewhat convex to the anterior and being nearly straight lines posteriorly; petals terminated about two-thirds the distance from the apex to the ambitus; ambulacra widen rapidly below petals. Posterior ambulacra petaloid, somewhat longer than the anterior, both poriferous areas concave toward a medial line; petals reach three-fifths of distance to ambitus from apex. Peristome anterior. Periproct with major diameter transverse (width 12 mm., height 6 mm.), elliptical in outline and lying close to upper edge of posterior truncation. Large tubercles scrobiculate, occurring only in interambulacral areas; most numerous in anterior interambulacral areas in the anterior portions; five primary tubercles in the anterior row of plates of the posterior paired interambulacrals; only one in the posterior plate row of the same areas; several also occur along the crest of the ridge in the posterior interambulacrum. Granules found over the whole of test. Measurements: Length, 72.5 mm.; width, 77.0 mm.; height, 29.3 mm. (Israelsky.)

REMARKS: In addition to the type specimen of *Spatangus rarus,* we have examined two imperfect specimens, the larger 82 mm. in length, from Loc. 122 (LAM), Pacific Beach, San Diego; but these add no new information concerning this species.

Israelsky mentioned that this species more closely resembles some of the species from the late Tertiary of Europe, especially *Spatangus corsicus* Desor[120] than it does the Recent west American *S. californicus* H. L. Clark[121].

A form from the Miocene of western Ukraine described by Szörényi[122] has wide ambulacral petals reminiscent of *Spatangus rarus;* but it differs somewhat in shape, and the apical system appears to be more anteriorly placed.

Family **LOVENIIDAE** Lambert, emended Mortensen

Differs from all other Spatangoids by the presence of an "inner" or "internal" fasciole, surrounding only the frontal ambulacrum and the apical system. (Mortensen, 1951.) Paleogene to Recent. (Durham and Melville.)

Genus **LOVENIA** Desor

Lovenia Desor in L. Agassiz and Desor, Ann. Sci. Nat. (Zool.), Ser. 3, Vol. 6, pl. 16, fig. 16; Vol. 8, pp. 10, 11, July, 1847. —H. L. Clark, Mem. Mus. Comp. Zool., Vol. 46, No. 2, p. 251, 1917. "Type, *Lovenia hystrix* Agassiz and Desor, 1847 =*Spatangus elongatus* Gray, 1845, Eyre, Voy. 1, p. 436."—Lambert and Thiéry, Essai Nomencl. Raison. Echinid., Fasc. 6 & 7, p. 466, 1924. "Type: *L. elongata* Gray (*Spatangus*) vivant de l'Océan Indien, dont *L. hystrix* Desor est un simple synonyme."—Grant and Hertlein, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 2, p. 135, 1938. "Type of the genus (by monotypy): *Lovenia 'Hystrix* Desor' . . . =*Spatangus elongatus* Gray."—Mortensen, Monogr. Echin. V.2. Spatangoida.II, p. 89, December 20, 1951. "Genotype: *Lovenia elongata* (Gray)."

TYPE SPECIES (by monotypy): "*Hystrix* Desor. —Descript. Egypt. Zool., Pl. 7, fig. 4," in L. Agassiz and Desor, Ann. Sci. Nat. (Zool.), Ser. 3, Vol. 8, p. 11, pl. 16 (Vol. 6), fig. 16, 1847. "Mer Rouge (Botta). —Mus. Paris." [= *Spatangus elongatus* Gray in E. J. Eyre, Jour. Centr. Austral., Vol. 1, p. 436, pl. 6, fig. 2, 1845. Australia. Illustrated by A. Agassiz, Illustr. Cat. Mus. Comp. Zool., No. 7 (Mem. Mus. Comp. Zool., Vol. 3), Pt. 1, p. 139, 1872; Pt. 3, p. 575, pl. 19c, figs. 1-4; pl. 25, fig. 31; pl. 26, figs. 35, 36; pl. 37, figs. 17, 18; pl. 38, figs. 27, 28, 1873. "Red Sea; Australia; Philippine Islands." Also Zanzibar. —Mortensen, 1951, p. 97, figs. 48a, 49, 50, 51, 52a;

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(120) *Spatangus corsicus* Desor in L. Agassiz and Desor, Ann. Sci. Nat. (Zool.), Ser. 3, Vol. 8, p. 7, July, 1847. "Tert. de Balestro (Corse), Saint-Paul-Trois-Châteaux (Drôme)." Figured by Loriol, Direction des Travaux Géologiques du Portugal. Description des Échinodermes Tertiaires du Portugal, pp. 47-48, pl. 13, figs. 3, 3a, 3b, 1896. "Bassin du Tage." Also "Santa Manza, Balistro, (Corse). (Helvétien).—Sardaigne. (Langhien)."

(121) *Spatangus californicus* H. L. Clark, Mem. Mus. Comp. Zool., Vol. 46, No. 2, p. 235, pl. 146, fig. 20; pl. 149, fig. 4; pl. 156, figs. 1-3; pl. 157, fig. 10, March, 1917. "Off southern California." "68 fms." Bathymetric range, 45-73 fathoms. Extremes of temperature, 56.5°-42.4°F.—Grant and Hertlein, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 2, p. 132, pl. 10, fig. 5; pl. 30, fig. 5, 1938. Off southern California to Cedros Island, Lower California. It also occurs at least as far north as Cordell Bank in central California. See also Mortensen (1951, p. 16, pl. 2, figs. 1, 2).

This species was cited erroneously as *Spatangus pacificus* by Israelsky (1923, p. 383).

(122) *Prospatangus* n. sp., Szörényi, Geol. Hungarica, Ser. Palaeo., Fasc. 23, p. 91, pl. 7, fig. 6, 1953. "Grabnik," western Ukraine. Miocene.

pl. 7, figs. 1-10; pl. 8, fig. 1; pl. 12, fig. 5; pl. 47, figs. 10-23. Indo-Pacific. See also H. L. Clark, Carnegie Inst. Washington, Publ. 566, p. 381, 1946. North Australia, South Africa, and Aden to Misaki, Japan.]

RANGE: Miocene to Recent. Cosmopolitan. Bathymetric range, in west American waters (*L. cordiformis*), usually from ebb tide to 137 meters (75 fathoms); one species in the Indo-Pacific (*L. gregalis* Alcock) occurs to a depth of 930 meters (509 fathoms) according to Mortensen (1951, p. 123).

DESCRIPTION: An internal fasciole present but no peripetalous; large, deeply sunken primary tubercles present in interambulacra on both upper and lower surfaces; sternum with tubercles confined to posterior part; petals I and V well formed. (H. L. Clark, 1925.)

REMARKS: *Pseudolovenia* A. Agassiz and H. L. Clark[123] is believed to be closely related to *Lovenia,* but it differs in that petals I and V are not at all petaloid and that the anterior petals are longer and narrower.

Only two species of *Lovenia* have been described from western North America: *L. hemphilli* Israelsky from Pliocene strata at San Diego, and *L. cordiformis* A. Agassiz, a Recent species described from Guaymas and the Gulf of California, ranging from Point Conception, California, to Panama, from the intertidal zone to a depth of 137 meters (75 fathoms). Mortensen recognized nine species and one variety of *Lovenia* as now living. The genus has not been reported from the Atlantic Ocean, but it is represented by fossil forms in late Tertiary strata in that region.

Lovenia hemphilli Israelsky

Plate 24, Figures 1-3, 18

Lovenia hemphilli Israelsky, Univ. Calif. Publ. Bull. Dept. Geol. Sci., Vol. 14, No. 11, p. 384, pl. 74, figs. 1a-1c, 2, November 7, 1923. "Pacific Beach, San Diego Co., California," Pliocene.—Grant and Hertlein, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 2, p. 137, pl. 13, figs. 3, 4, 1938. "Pacific Beach, San Diego"; "near Market Street and Euclid Avenue, San Diego."—Hertlein and Grant, Mem. San Diego Soc. Nat. Hist., Vol. 2, p. 57, 1944. "Pacific Beach."—Durham, Geol. Soc. Amer., Mem. 43, Pt. 2, p. 51, pl. 44, figs. 2, 6 (Monserrate Island, Pliocene), 3, 4 (San Diego Pliocene), 1950. "San Diego Pliocene."—Hertlein and Grant, Calif. State Div. Mines, Bull. 170, chapter 2, p. 60, 1954 (1955). "San Diego formation."

TYPE SPECIMEN: "Cotypes" [Syntypes] Nos. 918 and 919, Type Collection, Department of Geology, California Academy of Sciences.

TYPE LOCALITY: "Pacific Beach, San Diego Co., California." "Pliocene, San Diego formation." In "Micaceous sandstone."

RANGE: Middle Pliocene in southern California and at Monserrate Island, Gulf of California.

OCCURRENCE IN THE SAN DIEGO FORMATION: CALIFORNIA ACADEMY OF SCIENCES: Loc. 547, Pacific Beach (Israelsky; Grant and Hertlein); Loc. 1399, road cut 0.1 mile east of Euclid Avenue on Market Street; Loc. 1413, lower beds in Pliocene section at Pacific Beach; Loc. 1414, middle beds in Pliocene section at Pacific Beach. LOS ANGELES COUNTY MUSEUM: (?)Loc. 107, 100-foot bluff, with scattered fossiliferous concretions in clay quarry at end of Arroyo Drive, San Diego; Loc. 122, 20 to 30 feet below end of Loring Street, Pacific Beach.

ORIGINAL DESCRIPTION: Outline of test from above slightly cordiform, notched anteriorly, narrowed, and shallowly truncated posteriorly, greatest width slightly anterior to the apical system; greatest height posterior to apical system about two-thirds of distance from that system to the posterior truncation in the odd interambulacral area which is somewhat ridged. Apical system forward of center of test. Anterior odd ambulacrum in groove which reaches from the ambitus nearly to the apex. Antero-lateral petals sub-triangular, pointed anteriorly, slightly depressed, aborted by internal fasciole near the apical system, with anterior pore rows approximating a straight line transverse to the major diameter of the test; petals reach two-thirds of distance to ambitus. Postero-lateral petals nearly twice as long as the anterior, more lanceolate in outline, posterior pore rows forming an angle of about 80° one with the other. Pores in petals large, zygose. Primary tubercles present in all interambulacra excepting the odd posterior, the number varying with the individual (age factor); deeply scrobiculate, reflected internally by overlapping rings; primaries not found on ambital area. Miliaries found over

(123) *Pseudolovenia* A. Agassiz and H. L. Clark, Bull. Mus. Comp. Zool., Vol. 50, No. 8, p. 255, March, 1907. Type (by monotypy): *Pseudolovenia hirsuta* A. Agassiz and H. L. Clark. Several localities off the Hawaiian Islands in 192-692 fathoms. Figured by H. L. Clark, Mem. Mus. Comp. Zool., Vol. 46, No. 2, pp. 258-261, pl. 146, figs. 32, 33; pl. 160, figs. 8-12, 1917. Hawaiian Islands and Japan.

entire test. Peristome anterior to center of actinal side. Periproct posterior, lying in upper portion of deeply sunken depression which obliquely truncates the test at rear. (Israelsky.)

Measurements [Israelsky]:	Cotype No. 918, CAS	Cotype No. 919, CAS
Length	75.0 mm.	79.5 mm.
Width	63.1 mm.	67.3 mm.
Height	19.9 mm.	20.5 mm.

REMARKS: Eight specimens of this species in various states of preservation were collected by George P. Kanakoff and J. F. Arndt at Loc. 122 (LAM), Pacific Beach. These vary in length from 74.6 mm. to 82 mm. and in width from 56 mm. to 62 mm. In addition to these and the syntypes, we have studied a few other specimens, mostly incomplete ones, from Pacific Beach and from other localities. The exposed portions of all the specimens available to us from the San Diego area reveal the characteristic features of the syntypes.

Lovenia hemphilli differs from the Recent west American *L. cordiformis* A. Agassiz[124] in that the test is lower in proportion to the length and that the posterior truncation is sloping rather than nearly vertical. *Lovenia cordiformis* ranges[125] from Point Concepcion, California, to Panama and the Galapagos Islands, from shore to a depth of 137 meters (75 fathoms). Mortensen (1951, p. 108) thought that either *L. hemphilli* or *L. dumblei* Dickerson and Kew[126] might be the ancestor of *L. cordiformis*.

Israelsky pointed out the resemblance of *L. hemphilli* to *L. elongata* Gray (= *L. hystrix*, type species of *Lovenia*), but it differs in the character of the petals. He also called attention to the striking resemblance of *L. hemphilli* to *Sarsella duncani* Gregory[127], described from Oligocene Globigerina limestone of Malta.

L. hemphilli resembles members of the *L. elongata* group, which includes *L. camarota* H. L. Clark[128], *L. elongata* Gray, *L. cordiformis* A. Agassiz, and *L. hawaiiensis* Mortensen. *Lovenia similis* H. L. Clark[129], from Miocene strata in Fiji, may be another member of this group; but Mortensen expressed doubt that it is referable to the genus *Lovenia*. He suggested that it might belong to the genus *Breynia* Desor.

Family SCHIZASTERIDAE Lambert

The main character of this family is the presence (excepting *Amphipneustes*) of both a peripetalous and a latero-anal fasciole. (Mortensen, 1951.) Late Cretaceous to Recent.

Genus BRISASTER Gray

Brisaster Gray, Cat. Rec. Echin. Brit. Mus., p. 61, 1855. Species cited: *Schizaster fragilis* Düben and Koren (*Brissus fragilis* Düben and Koren), "Hab. Shores of Finmark"; *Schizaster gibberulus* Agassiz and Desor, "Hab. Red Sea"; *Schizaster cubensis* d'Orbigny, "Hab. Cuba, D'Orbigny".—H. L. Clark, Cat. Rec. Sea-Urchins Brit. Mus., p. 206, 1925. "Type, *Brissus fragilis* Düben and Koren".—Grant and Hertlein, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 2, p. 122, April 19, 1938. Type as in preceding reference.—Mortensen, Monogr. Echin., V.2. Spatangoida. II, p. 280, December 20, 1951. "Genotype: *Brisaster fragilis* (Düben & Koren)."

Lymanaster Lambert in Castex and Lambert, Actes Soc. Linn. Bordeaux, Vol. 71, p. 52, 1920. Type: *Brisaster townsendi* A. Agassiz.

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(124) *Lovenia cordiformis* A. Agassiz, Bull. Mus. Comp. Zool., Vol. 3, No. 4, p. 57, 1872. "Mus. Comp. Zoöl. Guayamas; Smith. Coll. Gulf of California." Footnote states "Lütken MS. in litt."—Grant and Hertlein, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 2, p. 136, pl. 11, figs. 2, 3; pl. 13, figs. 1, 2, 1938. Pleistocene and Recent. [Mortensen (1951, V.2, p. 107) considered Lütken to be the author of this species and Guayaquil, Ecuador, to be the type locality.]

(125) *Lovenia cordiformis* was recorded from the Hawaiian Islands by Ziesenhenne (1937, p. 236) and by H. L. Clark. Mortensen doubted the Hawaiian occurrences, believing that those records may be referable to *L. hawaiiensis* Mortensen (see Mortensen 1951, p. 107, pl. 13, figs. 24-30; pl. 48, figs. 2, 6, 7).

(126) *Lovenia dumblei* Dickerson and Kew, Proc. Calif. Acad. Sci., Ser. 4, Vol. 7, p. 136, pl. 17, figs. 2a-2c, July 30, 1917. Type locality, "Nuevo Rancho, 35 kilometers northwest of Tuxpan, near Cerro Azul," Mexico. "Upper Oligocene or Miocene."

(127) *Sarsella duncani* Gregory, Trans. Roy. Soc. Edinburgh, Vol. 36, Pt. 3, p. 624, 1890-1891 (May 10, 1892). Ref. to *Spatangus ocellatus* Defrance of T. Wright (*non* Defrance, 1827), Quart. Jour. Geol. Soc. London, Vol. 20, pp. 487-488, pl. 21, figs. 1a, 1b, 1864.

(128) *Lovenia camarota* H. L. Clark, Mem. Mus. Comp. Zool., Vol. 46, No. 2, p. 253, pl. 161, figs. 1-4, March, 1917 . . . . "west of Torres Strait, 28 fms., mud."

(129) *Lovenia similis* H. L. Clark, Bernice P. Bishop Mus., Bull. 181, p. 327, pl. 43, fig. G, January, 1945. "Oneata," Island of Lau group, Fiji, probably late Miocene.

TYPE SPECIES (designated by Lambert, Mém. Soc. Geol. France, Paléo., Tom. 14, Fasc. 2-3 (Mém. No. 24) p. 112, 1906): *Brisaster fragilis* Düben and Koren [= *Brissus fragilis* Düben and Koren, Kgl. Vetensk. Akad. Handl., p. 280, Tab. 10, figs. 47-49, 1844. Illustrated by Mortensen, 1951, pl. 23, figs. 1, 16-19. (Synon. pp. 283-284). Barents Sea, Murman coast and North Atlantic to Bergen, Norway, and Iceland and from Lat. 66°N. to Florida in west Atlantic, in 40 to 1300 meters.]

RANGE: Eocene to Recent (Lambert and Thiéry, 1925). [According to Mortensen, many of the species referred to *Brisaster* by Lambert and Thiéry are not referable to that genus.] Recent in North Atlantic, South Atlantic, eastern Pacific, and Japan, in 35 to 1900 meters (19 to 1039 fathoms).

DESCRIPTION: Test low, apex posterior; genital pores 3; posterior petals relatively short; petals II and IV at first little divergent, then becoming more so, and at tip markedly curved outward. (H. L. Clark, 1925.)

REMARKS: *Brisaster* is represented in the Oligocene of Oregon by *B. maximus* H. L. Clark, and in the Pliocene of California by *Brisaster* cf. *B. townsendi* A. Agassiz, by a subspecies described here as *B. townsendi woynari,* and perhaps by *"Schizaster (?)" stalderi* Weaver.

Seven species of this genus are recorded by Mortensen as occurring in the seas at the present time.

The test of *Faorina* Gray, which also possesses 3 genital pores, has the apical system nearly central, and the peripetalous fasciole is double anteriorly.

Brisaster townsendi woynari Hertlein and Grant, new subspecies

Plate 25, Figure 5; Plate 26, Figures 1-3

DESCRIPTION: Test is similar to that of *Brisaster townsendi* A. Agassiz in general features. The apex is about two-fifths of the distance from the posterior end, and the petals of the bivium, angle about 100°, are a little more than one-half the length of petals II and IV. The subspecies differs from typical *B. townsendi* in the greater size and more nearly quadrate outline of the test and in the more nearly central position of the apical system. Spines on the plastron are about 8 mm. in length. The test may be slightly crushed as a result of the compaction of the sediment, but the specimens available are comparatively uniform in outline. Dimensions are as follows: holotype, length 91.5 mm., width 90 mm., height 34.5 mm.; paratype, length 90 mm., width 92 mm., height 35.5 mm.; paratype, length 92 mm., width 91.8 mm., height 35.5 mm.

Two large specimens, slightly crushed and partly covered with concretionary material, have the following measurements: the larger one, length 97 mm., width 101 mm., height 33 mm.; the other one, length 94 mm., width 91 mm., height 32.5 mm.

TYPE SPECIMENS: Holotype and Paratypes, Invertebrate Paleontology Collection, Los Angeles County Museum.

TYPE LOCALITY: Loc. 107 (LAM), 100-foot bluff with scattered fossiliferous concretions in clay quarry at end of Arroyo Drive, San Diego; C. W. Woynar, coll.; San Diego formation, Pliocene.

RANGE: Known only from the type locality.

REMARKS: Portions of the specimens of this new subspecies are covered with a very hard matrix of sandstone, but most of the shell characters are revealed. The angle of the bivium is about 100°, whereas in the Recent *Brisaster townsendi* A. Agassiz[130] the angle is about 105 to 110°. This apparent difference may not be significant, for Mortensen has pointed out that anomalies in the form of the bivium occur in Recent specimens of *B. townsendi.* However, taken as a whole, the characters enumerated in the description of the present fossil form appear to differ from those of the Recent species sufficiently to justify its status as a distinct subspecies.

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(130) *Schizaster townsendi* A. Agassiz, Bull. Mus. Comp. Zool., Vol. 32, No. 5, p. 82, June, 1898. Gulf of Panama, 146-995 fathoms and 50 miles south of Guaymas, Mexico, in 628 fathoms.

Brisaster townsendi A. Agassiz, Grant and Hertlein, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 2, p. 123, pl. 1, fig. 6; pl. 14, figs. 1-3, 1938. Earlier records cited; also various records from western North America. Pliocene to Recent. —H. L. Clark, Allan Hancock Pac. Exped., Vol. 8, No. 5, p. 340, pl. 64, fig. 64, 1948. Southeastern Alaska to the Galapagos Islands in 20 to 995 fathoms.—Mortensen, Monogr. Echin., V.2. Spatangoida. II, p. 288, pl. 24, figs. 1, 2, 9-19; pl. 53, figs. 21-27, 1951. Southeastern Alaska to Panama, 35-1900 meters.

An imperfectly preserved specimen of a *Brisaster* approximately 55.5 mm. long and 52.6 mm. wide, in the collections of the San Diego Society of Natural History, was collected by W. E. Pennington at Pacific Beach. The anterior portion of the aboral surface of the specimen, bearing a peripetalous fasciole, agrees with that of the present subspecies and likewise is similar to that of Recent specimens of *Brisaster townsendi* of comparable size except that ambulacrum III is narrower. This latter feature might be due to compaction of the sediment.

A fragment of a sea-biscuit, 46 mm. long, from Loc. 122 (LAM), Pacific Beach, appears to be referable to the genus *Brisaster*. It may, perhaps, represent a young specimen of the new subspecies described above.

The largest specimen of Recent *Brisaster townsendi* A. Agassiz that we have seen is one measuring 70 mm. in length from Loc. 24834 (CAS), off Bainbridge Island, Washington, in 219 meters (120 fathoms). Mortensen (1951, p. 289) mentioned a specimen 77 mm. in length. According to the same author, the type species of the genus, *B. fragilis*, attains a length of 90 mm. A series of specimens of *B. townsendi* shows considerable variation in the degree of flatness of the abactinal surface.

The present authors (1938, p. 123) recorded a specimen under the name of "*Brisaster* cf. *townsendi*" from strata of Pliocene age from a well in Orange County, California. Mortensen (1951, p. 282) suggested that the species described as *Schizaster* (?) *stalderi* by Weaver[131] from Pliocene beds in northern California is probably referable to the genus *Brisaster*. The only other species of this genus recorded as a fossil from western North America is *Brisaster maximus* H. L. Clark[132] (length about 84 mm., width approximately 76 mm.) from beds of Oligocene age in western Oregon.

Brisaster townsendi ranges from the Bering Sea to the Gulf of California and south to Panama, in 20 to 1900 meters (11 to 1039 fathoms). It is abundant off the coast of California in 91 to 146 meters (50 to 80 fathoms).

This new subspecies is named for Mr. William C. Woynar, San Diego, California, who collected the type specimens.

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(131) *Schizaster* (?) *stalderi* Weaver, Univ. Calif. Publ. Bull. Dept. Geol., Vol. 5, No. 17, p. 274, pl. 21, fig. 3, December 28, 1908. "Humboldt County, California, in beds presumed to represent the Wild Cat series of Lawson."—Grant and Hertlein, Publ. Univ. Calif. Los Angeles Math. Phys. Sci., Vol. 2, p. 121, pl. 25, fig. 6, 1938. Earlier records cited. Pliocene.

(132) *Brisaster maximus* H. L. Clark, Trans. San Diego Soc. Nat. Hist., Vol. 8, No. 28, p. 368, pl. 24, fig. 9, December 15, 1937.—Weaver, Univ. Washington Publ. Geol., Vol. 5, p. 11, pl. 4, fig. 5, issued December 31, 1943.

PLATES 19 TO 26

EXPLANATION OF PLATE 19

FIG. 1. *Astrangia* cf. *A. insignifica* Nomland. Hypotype (Los Angeles County Museum), from Loc. 305 (LAM), 2400 feet east and 1350 feet south of northwest corner of Sec. 8, T.19S., R.2W., San Bernardino Base and Meridian, southwestern San Diego County, California (see U.S. Geol. Surv. topographic map, San Ysidro quadrangle, ed. 1943). Diameter of calice 4.3 mm. P. 79

FIG. 2. *Astrangia* cf. *A. insignifica* Nomland. Hypotype (Los Angeles County Museum), from same locality as specimen shown in fig. 1. Diameter of calice 3.2 mm. P. 79

FIG. 3. *Astrangia* cf. *A. insignifica* Nomland. Side view of specimen shown in fig. 2.

FIG. 4. *Astrangia* cf. *A. insignifica* Nomland. Base of specimen shown in figs. 2 and 3.

FIG. 5. *Dendrophyllia* cf. *D. oldroydi* Faustino. Hypotype (Los Angeles County Museum), from same locality as specimen shown in fig. 1, showing interior of calice. Length of specimen 19 mm. See also figs. 6 and 15 . P. 82

FIG. 6. *Dendrophyllia* cf. *D. oldroydi* Faustino. Hypotype (Los Angeles County Museum); same specimen as shown in figs. 5 and 15, showing branching character. P. 82

FIG. 7. *Astrangia* cf. *A. insignifica* Nomland. Base of specimen shown in fig. 1.

FIG. 8. *Paracyathus stearnsii* Verrill. Hypotype (Los Angeles County Museum), from same locality as specimen shown in fig. 1. Side view. Height 16.2 mm. P. 80

FIG. 9. *Paracyathus stearnsii* Verrill. Corallum of specimen shown in fig. 8. Greater diameter of calice 15 mm.; lesser diameter 11 mm. P. 80

FIG. 10. *Paracyathus stearnsii* Verrill. Hypotype (Los Angeles County Museum), from same locality as specimen shown in fig. 1. Height of specimen 9 mm.; greater diameter of calice 9 mm. P. 80

FIG. 11. *Paracyathus stearnsii* Verrill. Same specimen shown in fig. 10, showing character of budding.

FIG. 12. *Paracyathus stearnsii* Verrill. Hypotype (Los Angeles County Museum), from same locality as specimen shown in fig. 1. Exterior of portion of corallum. Height of specimen 7.8 mm. P. 80

FIG. 13. *Paracyathus stearnsii* Verrill. Hypotype (Los Angeles County Museum), from same locality as specimen shown in fig. 1. Greater diameter of calice approximately 11.3 mm.; lesser diameter 9.4 mm. P. 80

FIG. 14. *Balanophyllia elegans* Verrill. Hypotype (Los Angeles County Museum), from same locality as specimen shown in fig. 1, showing one individual attached to another. Height of specimen 10 mm. P. 84

FIG. 15. *Dendrophyllia* cf. *D. oldroydi* Faustino. Hypotype (Los Angeles County Museum); same specimen shown in figs. 5 and 6. Calice diameter 9.5 mm. P. 82

FIG. 16. *Terebratalia occidentalis* Dall. Hypotype (California Academy of Sciences), from Loc. 1419 (CAS), northeast corner of India and Thorn streets, San Diego, California. View of exterior of pedicle valve. Length 14.9 mm.; width 19.3 mm. P. 94

FIG. 17. *Glottidia albida* Hinds. Hypotype (University of California at Los Angeles), from Loc. L-309 (UCLA), southeast corner of India and Upas streets, San Diego, California. Length 12.5 mm.; width 8 mm. Interior of apical portion of pedicle valve, showing diverging laminae. P. 89

FIG. 18. *Glottidia albida* Hinds. Hypotype (Los Angeles County Museum), from same locality as specimen shown in fig. 1. Length 12 mm.; width 5.5 mm. Exterior of dorsal valve. P. 89

FIG. 19. *Balanophyllia elegans* Verrill. Hypotype (Los Angeles County Museum), from same locality as specimen shown in fig. 1. Height 21 mm.; maximum diameter 7 mm. P. 84

FIG. 20. *Balanophyllia elegans* Verrill. Hypotype (Los Angeles County Museum), from same locality as specimen shown in fig. 1. Height 13.8 mm.; maximum diameter 7.3 mm. P. 84

FIG. 21. *Balanophyllia elegans* Verrill. Hypotype (Los Angeles County Museum), from same locality as specimen shown in fig. 1. Height 15 mm.; maximum diameter approximately 7.5 mm. P. 84

FIG. 22. *Terebratalia occidentalis* Dall. Hypotype (California Academy of Sciences), from Loc. 28159 (CAS), Pacific Beach, San Diego, California. Length 16 mm.; width, incomplete, 20.4 mm. Exterior of dorsal valve. P. 94

FIG. 23. *Glottidia albida* Hinds. Hypotype (California Academy of Sciences), from Loc. 1401 (CAS), south slope of Soledad Mountain, San Diego, California. Length 9.3 mm.; width 5 mm. Exterior of dorsal valve. P. 89

FIG. 24. *Glottidia albida* Hinds. Hypotype (Los Angeles County Museum), 50 feet northeast of Loc. 107 (LAM), clay quarry at end of Arroyo Drive, San Diego, California. Length 19.9 mm.; width (one valve) approximately 7.8 mm. Exterior of dorsal valve. P. 89

FIG. 25. *Glottidia albida* Hinds. Hypotype (Los Angeles County Museum), from same locality as specimen shown in fig. 24. Length 21 mm.; width 10 mm. Exterior of pedicle valve. P. 89

FIG. 26. *Terebratalia hemphilli* Dall. Hypotype (Los Angeles County Museum), from Loc. 122 (LAM), Pacific Beach, San Diego, California. Length 38.9 mm.; width (incomplete) 38 mm. Exterior of pedicle valve. P. 93

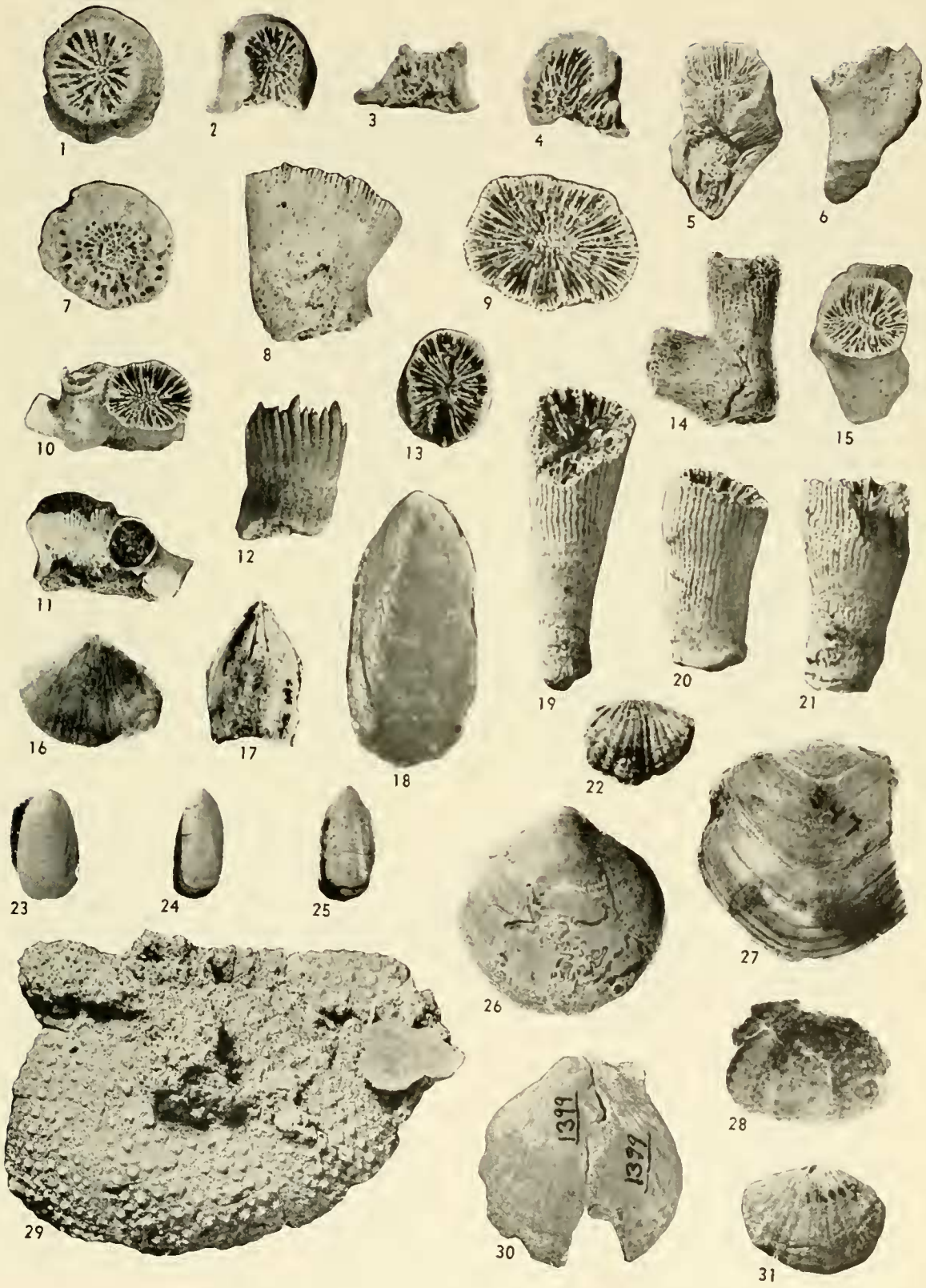
FIG. 27. *Terebratalia hemphilli* Dall. Hypotype (California Academy of Sciences), from Loc. 547 (CAS), Pacific Beach, San Diego, California. Length 40.6 mm.; width (incomplete) 38 mm. Exterior of brachial valve. P. 93

FIG. 28. *Strongylocentrotus franciscanus* A. Agassiz. Hypotype (California Academy of Sciences), from Loc. 12163 (CAS), Pacific Beach, San Diego, California. Portion of a small test. Diameter 21.5 mm. P. 111

FIG. 29. *Strongylocentrotus purpuratus* Stimpson. Hypotype (Los Angeles County Museum), from Loc. 153 (LAM), Pacific Beach, San Diego, California. Portion of somewhat crushed test. Diameter 79.6 mm. P. 112

FIG. 30. *Terebratalia arnoldi* Hertlein and Grant. Hypotype (California Academy of Sciences), from Loc. 1399 (CAS), Pacific Beach, San Diego, California. Length 41 mm.; width 39.3 mm. Exterior of pedicle valve. P. 92

FIG. 31. *Terebratalia occidentalis* Dall. Hypotype (No. 7324, California Academy of Sciences), from Loc. 12007 (CAS), Pacific Beach, San Diego, California. Length 21 mm.; width 27.2 mm.; convexity of brachial valve 5.7mm. Exterior of brachial valve. P. 94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EXPLANATION OF PLATE 20

FIG. 1. *Laqueus californianus* Koch. Hypotype (Los Angeles County Museum), from Loc. 107 (LAM), clay quarry at end of Arroyo Drive, San Diego, California. Length 38 mm.; width 33.3 mm.; convexity (both valves together) 18 mm. Pedicle valve. P. 96

FIG. 2. *Laqueus californianus* Koch. Dorsal view of specimen shown in fig. 1.

FIG. 3. *Laqueus californianus* Koch. Side view of specimen shown in figs. 1 and 2.

FIG. 4. *Laqueus vancouveriensis diegensis* Hertlein and Grant, new subspecies. Paratype (Los Angeles County Museum), from Loc. 122 (LAM), 20 to 30 feet below end of Loring Street, Pacific Beach, San Diego, California. Length 36.4 mm.; width 28 mm.; convexity (both valves together) 22.5 mm. Pedicle valve. P. 97

FIG. 5. *Laqueus californianus* Koch. Hypotype (Los Angeles County Museum), from same locality as specimen shown in fig. 1. Length 38.2 mm.; width 29 mm.; convexity (both valves together) 18.2 mm. Dorsal view. P. 96

FIG. 6. *Laqueus californianus* Koch. Dorsal view of specimen shown in fig. 5.

FIG. 7. *Laqueus californianus* Koch. Side view of specimen shown in figs. 5 and 6.

FIG. 8. *Laqueus vancouveriensis diegensis* Hertlein and Grant, new subspecies. Dorsal view of specimen shown in fig. 4.

FIG. 9. *Laqueus vancouveriensis diegensis* Hertlein and Grant new subspecies, Holotype (No. 7355, California Academy of Sciences), from Loc. 12005 (CAS), Pacific Beach, San Diego, California. Length 34.5 mm.; width 29.5 mm.; convexity (both valves together) 21.6 mm. Pedicle valve. P. 97

FIG. 10. *Laqueus vancouveriensis diegensis* Hertlein and Grant, new subspecies. Holotype. Dorsal view of specimen shown in fig. 9.

FIG. 11. *Laqueus vancouveriensis diegensis* Hertlein and Grant, new subspecies. Holotype. Side view of specimen shown in figs. 9 and 10.

FIG. 12. *Laqueus vancouveriensis diegensis* Hertlein and Grant, new subspecies. Side view of specimen shown in figs. 4 and 8.

FIG. 13. *Laqueus vancouveriensis diegensis* Hertlein and Grant, new subspecies. Paratype (No. 7354, California Academy of Sciences), from Loc. 537 (CAS), Pacific Beach, San Diego, California. Length 33.8 mm.; width 31 mm.; convexity (both valves together) 20.5 mm. Pedicle valve. P. 97

FIG. 14. *Laqueus vancouveriensis diegensis* Hertlein and Grant, new subspecies. Dorsal view of specimen shown in fig. 13.

FIG. 15. *Laqueus vancouveriensis diegensis* Hertlein and Grant, new subspecies. Side view of specimen shown in figs. 13 and 14.

FIG. 16. *Laqueus vancouveriensis diegensis* Hertlein and Grant, new subspecies. Paratype (San Diego Society of Natural History), from Loc. 726 (SD), Pacific Beach, San Diego, California. Length 30.6 mm.; width 24 mm.; convexity (both valves together) 20.3 mm. Pedicle valve. P. 97

FIG. 17. *Laqueus vancouveriensis diegensis* Hertlein and Grant, new subspecies. Dorsal view of specimen shown in fig. 16.

FIG. 18. *Laqueus vancouveriensis diegensis* Hertlein and Grant, new subspecies. Paratype (Cat. No. 2420, University of California at Los Angeles), bluffs along Pacific Beach, about ½ mile southeast of False Point, La Jolla quadrangle, San Diego, California. Length 35.9 mm.; width 32.5 mm.; convexity (pedicle valve) 11.2 mm. Exterior of pedicle valve. P. 97

FIG. 19. *Laqueus vancouveriensis diegensis* Hertlein and Grant, new subspecies. Interior of valve shown in fig. 18.

FIG. 20. *Laqueus vancouveriensis diegensis* Hertlein and Grant, new subspecies. Paratype (University of California at Los Angeles), from same locality as specimen shown in figs. 18 and 19. Length 35 mm.; width 33 mm.; convexity (both valves together) 16.4 mm. Specimen slightly crushed. Pedicle valve. P. 97

FIG. 21. *Laqueus vancouveriensis diegensis* Hertlein and Grant, new subspecies. Dorsal view of specimen shown in fig. 20.


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EXPLANATION OF PLATE 21

FIG. 1. *Dendraster ashleyi* Arnold. Hypotype (No. 6325, University of California at Los Angeles), from Quayle's Loc. 8, Las Chollas Valley, San Diego, California. Length 66 mm.; width 75 mm.; height approximately 11 mm. Aboral surface. P. 117

FIG. 2. *Dendraster ashleyi* Arnold. Hypotype (Los Angeles County Museum), from Loc. 306 (LAM), east side of Euclid Avenue between Federal Boulevard and intersection of Euclid and Home avenues, San Diego, California. Length 52.3 mm.; width 57 mm.; height approximately 8.5 mm. Oral surface. P. 117

FIG. 3. *Dendraster ashleyi* Arnold. Hypotype Cat. No. 3374, (University of California at Los Angeles), from Loc. 296 (UCLA), street cut on northwest side of Fairmount extension, 0.4 mile north of intersection with Broadway, on west side of Las Chollas Valley, San Diego, California. Length 58.9 mm.; width 66.7 mm.; height approximately 9.2 mm. Aboral surface. P. 117

FIG. 4. *Dendraster ashleyi ynezensis* Kew. Hypotype (Los Angeles County Museum), from Loc. 107 (LAM), clay quarry at end of Arroyo Drive, San Diego, California. Length 77.6 mm.; width 86 mm.; height approximately 10.5 mm. Oral surface, with spines. G. P. Kanakoff, collector. P. 118

FIG. 5. *Dendraster ashleyi ynezensis* Kew. Hypotype (Los Angeles County Museum), from Loc. 127 (LAM), at Encanto, Wabash Freeway, Market Street continuation, ¼ mile south of Euclid Avenue, San Diego, California. Length 76 mm.; width 85.3 mm.; height approximately 9.0 mm. Aboral surface. P. 118

FIG. 6. *Dendraster ashleyi* Arnold. Hypotype (Los Angeles County Museum), from 2400 block, east side of Euclid Avenue, San Diego, California. Length 58.5 mm.; width 66.2 mm.; height 9.0 mm. P. 117

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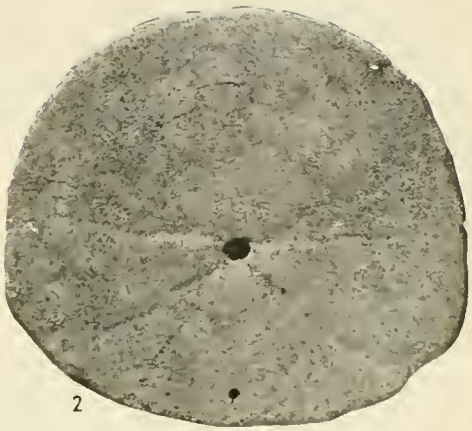

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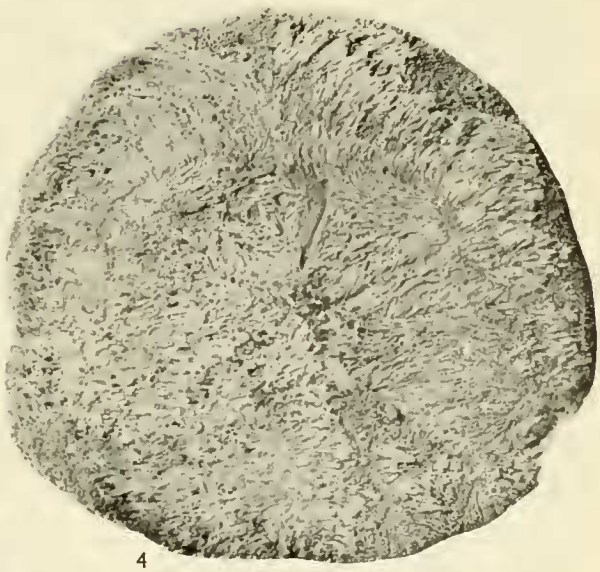

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EXPLANATION OF PLATE 22

FIG. 1. *Dendraster ashleyi* Arnold. Hypotype (Los Angeles County Museum), from Loc. 306 (LAM), on east side of Euclid Avenue, between Federal Boulevard and intersection of Euclid and Home avenues, San Diego, California. Length 58.7 mm.; width 66.8 mm.; height approximately 6.3 mm. Aboral surface. P. 117

FIG. 2. *Dendraster ashleyi ynezensis* Kew. Hypotype (Los Angeles County Museum), from Loc. 294 (LAM), back of house No. 3550 on Dove Street, San Diego, California. Length 20.5 mm.; width 20.6 mm.; height approximately 2.6 mm. Aboral surface of small specimen. P. 118

FIG. 3. *Dendraster ashleyi* Arnold. Hypotype (Cat. No. 3374, University of California at Los Angeles), from Loc. 296 (UCLA), street cut on northwest side of Fairmount extension, 0.4 mile north of intersection with Broadway, on west side of Las Chollas Valley, San Diego, California. Length 59 mm.; width 66.6 mm.; height 8.5 mm. Aboral surface. P. 117

FIG. 4. *Dendraster ashleyi ynezensis* Kew. Hypotype (University of California at Los Angeles), from same locality as specimen shown in fig. 3. Length 61.4 mm.; width 67 mm.; height 9.8 mm. Oral surface of specimen intermediate between *Dendraster ashleyi* and *D. a. ynezensis*. P. 118

FIG. 5. *Dendraster gibbsii humilis* Kew. Hypotype (California Academy of Sciences), from Loc. 12164 (CAS), Pacific Beach, San Diego, California. Length 44.2 mm.; width 48.2 mm.; height 9.5 mm. P. 120

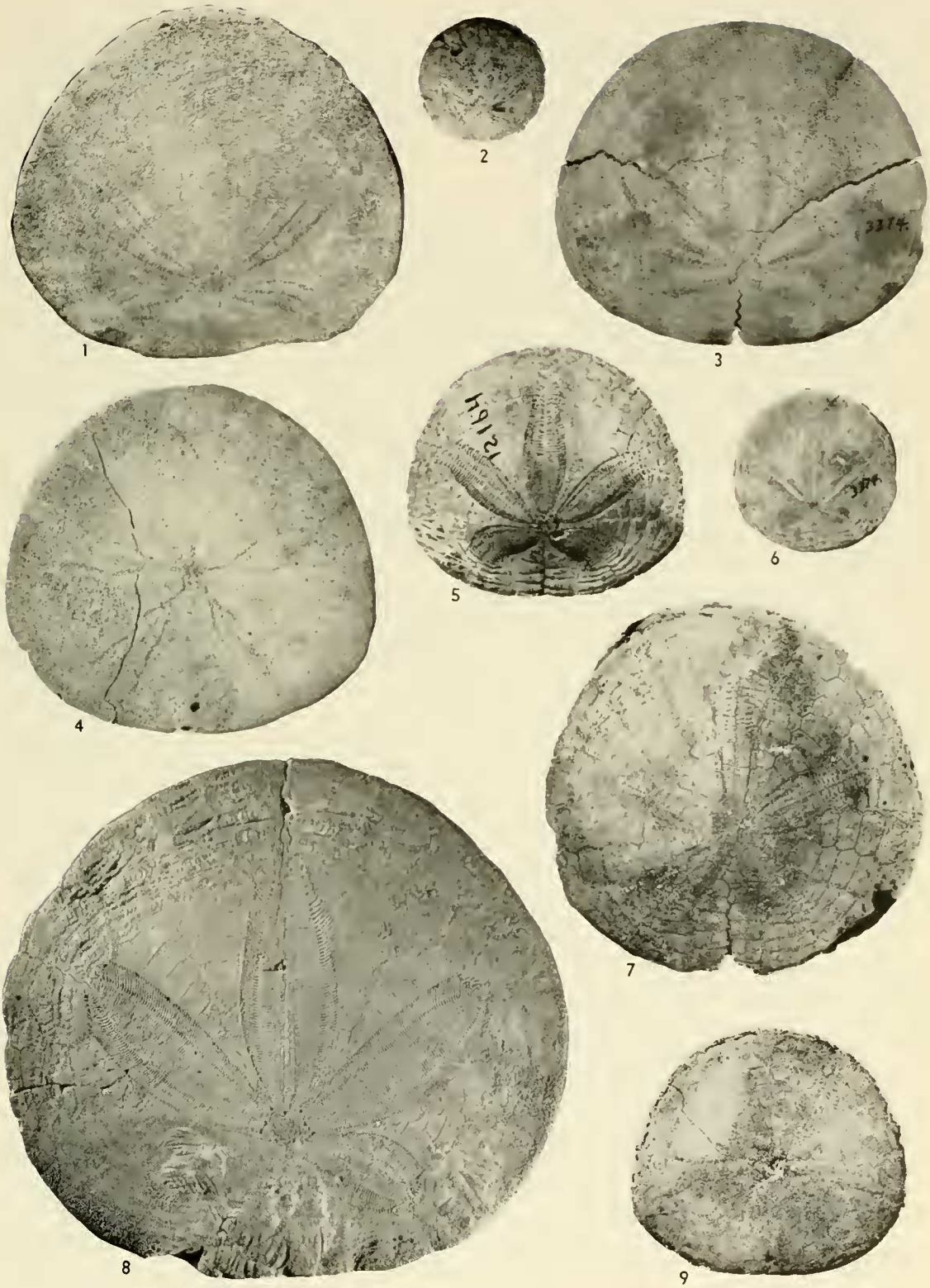
FIG. 6. *Dendraster ashleyi ynezensis* Kew. Hypotype (University of California at Los Angeles), from same locality as specimen shown in fig. 3. Length 28.6 mm.; width 29.9 mm.; height approximately 3 mm. Aboral surface of small specimen. P. 118

FIG. 7. *Dendraster casseli* Grant and Hertlein. Hypotype (Los Angeles County Museum), from Loc. 107 (LAM), clay quarry at end of Arroyo Drive, San Diego, California. Length 56.9 mm.; width 60.8 mm.; height approximately 6.3 mm. Aboral surface. P. 120

FIG. 8. *Dendraster ashleyi ynezensis* Kew. Hypotype (No. 4018, University of California at Los Angeles), from Las Chollas Valley, above Market Street bridge, San Diego, California; collected by E. H. Quayle. Length 88.3 mm.; width 98 mm.; height approximately 9.2 mm. Aboral surface.

This form is larger and rounder than typical *D. ashleyi*, and the angle of the bivium is smaller. P. 118

FIG. 9. *Dendraster gibbsii humilis* Kew. Oral surface of specimen shown in fig. 5.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EXPLANATION OF PLATE 23

FIG. 1. *Merriamaster pacificus* Kew. Holotype (No. 448, California Academy of Sciences), from Loc. 537 (CAS), Pacific Beach, San Diego, California. Length 36 mm.; width 35 mm.; height 8.3 mm. Aboral surface. P. 124

FIG. 2. *Merriamaster pacificus* Kew. Hypotype (Los Angeles County Museum), from Loc. 308 (LAM), 0.2 mile north of intersection of Harbor Boulevard and Tourmaline Street, Pacific Beach, San Diego, California. Length 28.5 mm.; width 27 mm.; height 7.3 mm. Aboral surface. P. 124

FIG. 3. *Merriamaster pacificus* Kew. Oral surface of specimen shown in fig. 2.

FIG. 4. *Merriamaster pacificus* Kew. Hypotype (Los Angeles County Museum), from same locality as specimen shown in fig. 2. Length 23 mm.; width 21 mm.; height 4.8 mm. Aboral surface of small specimen. P. 124

FIG. 5. *Merriamaster pacificus* Kew. Oral surface of specimen shown in fig. 1.

FIG. 6. *Merriamaster pacificus* Kew. Hypotype (Los Angeles County Museum), from Loc. 122 (LAM), 20 to 30 feet below end of Loring Street, Pacific Beach, San Diego, California. Length 28.3 mm.; width 26.7 mm.; height 6.4 mm. Oral surface. P. 124

FIG. 7. *Encope tenuis* Kew. Hypotype (Los Angeles County Museum), from Loc. 107 (LAM), clay quarry at end of Arroyo Drive, San Diego, California; G. P. Kanakoff, collector. Length 104 mm.; transverse diameter (incomplete) 97 mm.; height 12 mm. Aboral surface. P. 126

FIG. 8. *Astropecten armatus* Gray. Hypotype (University of California at Los Angeles), from corner of Market Street and Euclid Avenue, San Diego, California. Length 13.8 mm.; maximum width 12 mm. Aboral surface of fragment of ray. P. 100

FIG. 9. *Astropecten armatus* Gray. Oral surface of specimen shown in fig. 8.

FIG. 10. *Merriamaster* cf. *M. israelskyi* E. K. Jordan and Hertlein. Hypotype (San Diego Society of Natural History), from Balboa Park, San Diego, California. Length 43.4 mm.; width 43.4 mm. Oral surface. P. 122

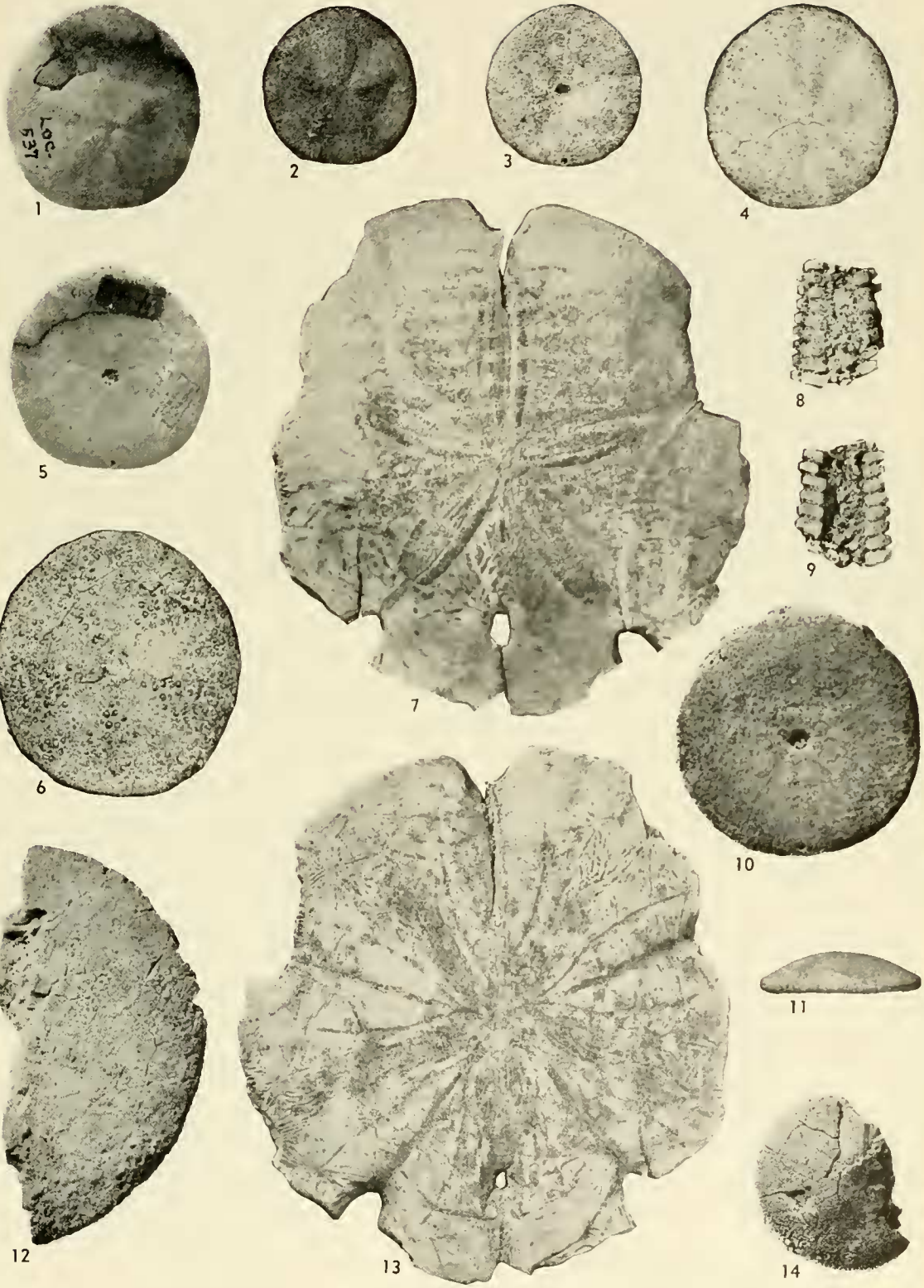
FIG. 11. *Merriamaster pacificus* Kew. Side view of specimen shown in figs. 2 and 3.

FIG. 12. *Merriamaster* cf. *M. israelskyi* E. K. Jordan and Hertlein. Hypotype (Los Angeles County Museum), from Loc. 124 (LAM), 15 feet below floor of Snyder Continuation School, San Diego, California. Length (incomplete) 71.8 mm.; width (incomplete) 41 mm. Oral surface of portion of large specimen. P. 122

FIG. 13.* *Encope tenuis* Kew. Oral surface of specimen shown in fig. 7.

FIG. 14. *Merriamaster* cf. *M. israelskyi* E. K. Jordan and Hertlein. Hypotype (Los Angeles County Museum), from same locality as specimen shown in fig. 12. Length 32.5 mm.; width (incomplete) 29.5 mm. Aboral surface of portion of specimen. P. 122

*Two details in figures 7 and 13 are inexact because of tooling out by the engraver. The small fissure at the central top margin, an imperfection in the fossil, is actually 4 mm. long; and the closed posterior lunule is oval in shape and 4 by 3 mm.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EXPLANATION OF PLATE 24

FIG. 1. *Lovenia hemphilli* Israelsky. Syntype (No. 918, California Academy of Sciences), from Loc. 12165 (CAS), Pacific Beach, San Diego, California. Length 75 mm.; width 63.1 mm.; height 19.9 mm. Aboral surface. P. 130

FIG. 2. *Lovenia hemphilli* Israelsky. Oral surface of specimen shown in fig. 1.

FIG. 3. *Lovenia hemphilli* Israelsky. Side view of specimen shown in figs. 1 and 2. Anterior end toward the right.

FIG. 4. *Balanophyllia elegans* Verrill. Hypotype (Los Angeles County Museum), from Loc. 305 (LAM), 2400 feet east and 1350 feet south of northwest corner of Sec. 8, T.19S., R.2W., San Bernardino Base and Meridian, southwestern San Diego County, California (see U.S. Geol. Surv. topographic map, San Ysidro quadrangle, ed. 1943). Height 16.6 mm.; maximum diameter of corallum 6.4 mm. P. 84

FIG. 5. *Balanophyllia elegans* Verrill. Hypotype (Los Angeles County Museum), from same locality as specimen shown in fig. 4. Height 15 mm.; maximum diameter of corallum 7 mm. P. 84

FIG. 6. *Hesperocidaris perplexa* H. L. Clark. Hypotype (California Academy of Sciences), from Loc. 1183 (CAS), Eagle Street just north of Quince Street and just east of Reynard Way, San Diego, California. Length 18.3 mm.; maximum diameter 2.9 mm. Portion of spine flattened at distal end, as is characteristic of this species. P. 105

FIG. 7. *Hesperocidaris perplexa* H. L. Clark. Hypotype (California Academy of Sciences), from same location as specimen shown in fig. 6. Length 21.1 mm.; maximum diameter 2.8 mm. Spine, lacking distal end. P. 105

FIG. 8. *Balanophyllia elegans* Verrill. Hypotype (Los Angeles County Museum), from same locality as specimen shown in fig. 4. Height 19.5 mm.; maximum diameter of corallum 9.3 mm. P. 84

FIG. 9. *Hesperocidaris perplexa* H. L. Clark. Hypotype (California Academy of Sciences), from Loc. 12163 (CAS), Pacific Beach, San Diego, California. Spine. Length 31 mm.; maximum diameter 3 mm. P. 105

FIG. 10. *Hesperocidaris perplexa* H. L. Clark. Hypotype (California Academy of Sciences), from same locality as specimen shown in fig. 6. Spine (incomplete). Length 26.6 mm.; maximum diameter 2.5 mm. P. 105

FIG. 11. *Encope tenuis* Kew. Side view of specimen shown on plate 23, figs. 7, 13. Anterior end toward the right. P. 126

FIG. 12. *Hesperocidaris perplexa* H. L. Clark. Hypotype (San Diego Society of Natural History), from Pacific Beach, San Diego, California. Maximum length of specimen 32.4 mm. Plates with primary and secondary tubercles. P. 105

FIG. 13. *Balanophyllia elegans* Verrill. Hypotype (Los Angeles County Museum), from the same locality as specimen shown in fig. 4. Height 16.4 mm.; maximum diameter of calice 5.6 mm. P. 84

FIG. 14. *Hesperocidaris perplexa* H. L. Clark. Hypotype (California Academy of Sciences), from same locality as specimen shown in fig. 6. Spine (incomplete). Length 18.3 mm.; maximum diameter 2.7 mm. P. 105

FIG. 15. *Balanophyllia elegans* Verrill. Hypotype (Los Angeles County Museum), from same locality as specimen shown in fig. 4. Height 14.2 mm.; maximum diameter of calice 6.8 mm. P. 84

FIG. 16. *Balanophyllia elegans* Verrill. Hypotype (Los Angeles County Museum), from same locality as specimen shown in fig. 4. Height 12 mm.; maximum diameter of calice 7.3 mm. P. 84

FIG. 17. *Balanophyllia elegans* Verrill. Hypotype (Los Angeles County Museum), from same locality as specimen shown in fig. 4. Height 17 mm.; maximum diameter of calice 6 mm. P. 84

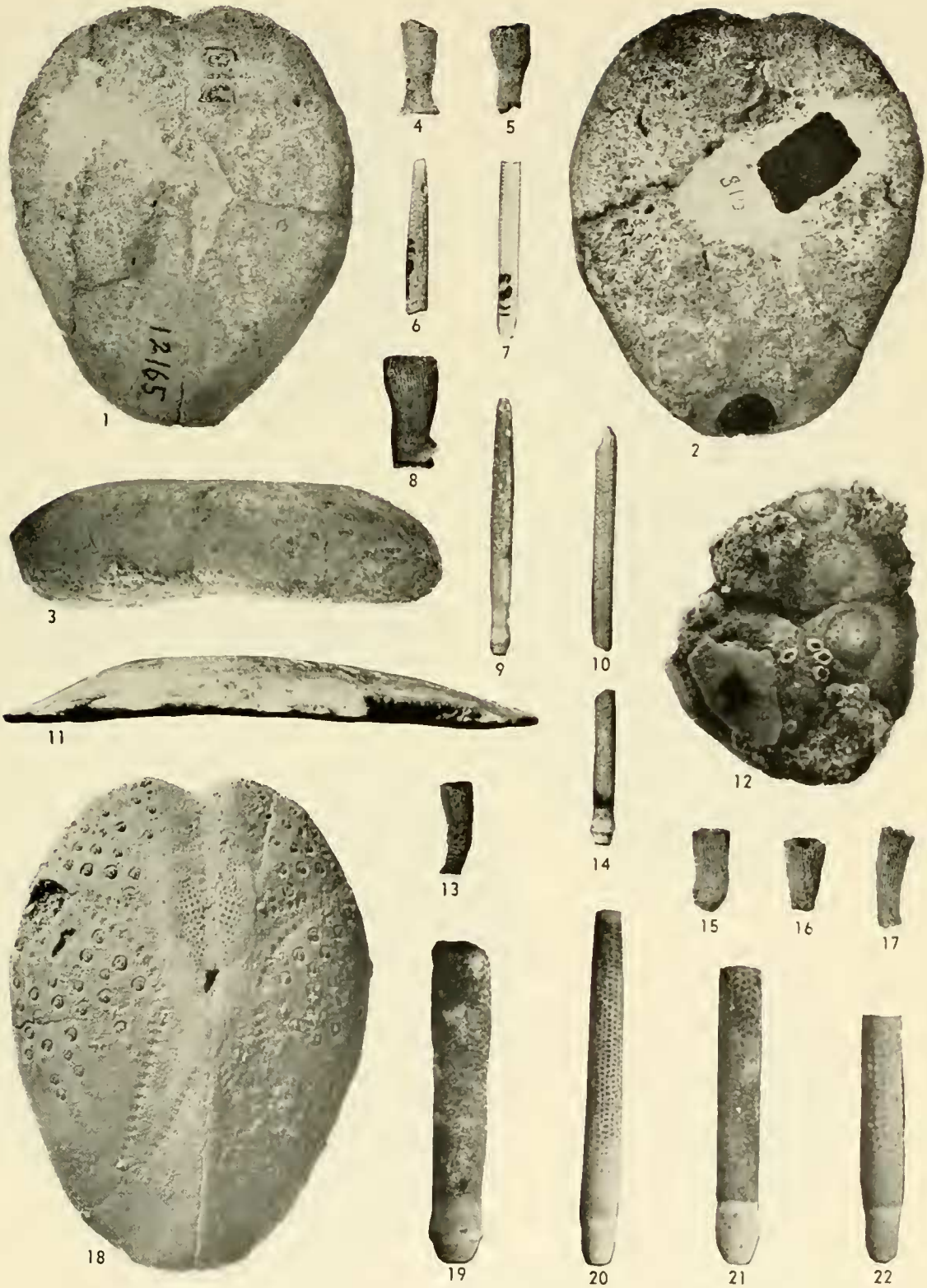
FIG. 18. *Lovenia hemphilli* Israelsky. Hypotype (Los Angeles County Museum), from Loc. 122 (LAM), 20 to 30 feet below end of Loring Street, Pacific Beach, San Diego, California. Length 82 mm.; width 62 mm.; height 22 mm. Aboral surface. P. 130

FIG. 19. *Eucidaris* cf. *E. thouarsii* Valenciennes. Hypotype (Los Angeles County Museum), from same locality as specimen shown in fig. 4. Spine (incomplete). Length 27 mm.; maximum diameter 5.2 mm. P. 103

FIG. 20. *Eucidaris* cf. *E. thouarsii* Valenciennes. Hypotype (Los Angeles County Museum), from same locality as specimen shown in fig. 4. Spine. Length 30 mm.; maximum diameter 3.4 mm. P. 103

FIG. 21. *Eucidaris* cf. *E. thouarsii* Valenciennes. Hypotype (Los Angeles County Museum), from same locality as specimen shown in fig. 4. Spine (incomplete). Length 25 mm.; maximum diameter 3.7 mm. P. 103

FIG. 22. *Eucidaris* cf. *E. thouarsii* Valenciennes. Hypotype (Los Angeles County Museum), from same locality as specimen shown in fig. 4. Spine (incomplete). Length 21 mm.; maximum diameter 3.6 mm. P. 103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EXPLANATION OF PLATE 25

FIG. 1. *Spatangus rarus* Israelsky. Holotype (No. 917, California Academy of Sciences), from Loc. 547 (CAS), Pacific Beach, San Diego, California. Length 72.5 mm.; width 77.0 mm.; height 29.3 mm. Aboral surface. P. 128

FIG. 2. *Spatangus rarus* Israelsky. Oral surface of specimen shown in fig. 1.

FIG. 3. *Spatangus rarus* Israelsky. Side view of specimen shown in figs. 1 and 2. Anterior end toward the right.

FIG. 4. *Encope tenuis* Kew. Hypotype (San Diego Society of Natural History), from 31st Street and Logan Avenue, San Diego, California. Length approximately 74 mm. Aboral surface. P. 126

FIG. 5. *Brisaster townsendi woynari* Hertlein and Grant, new subspecies. Paratype (Los Angeles County Museum), from Loc. 107 (LAM), clay quarry at end of Arroyo Drive, San Diego, California. Length 92 mm.; width 91.8 mm.; height 35.5 mm. Aboral surface. P. 132

FIG. 6. *Merriamaster pacificus* Kew. Aboral surface of specimen (slightly crushed) shown on plate 26, fig. 11.

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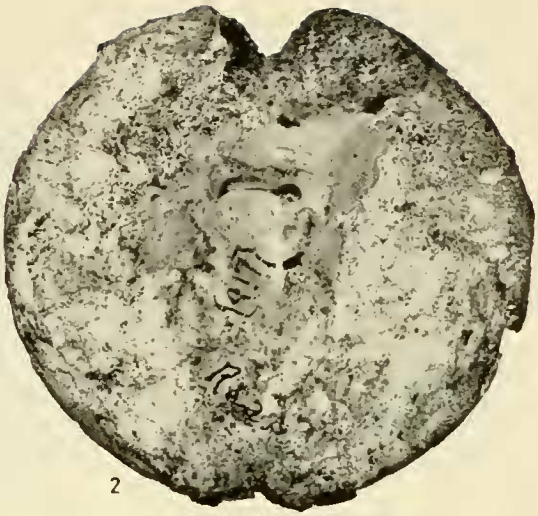

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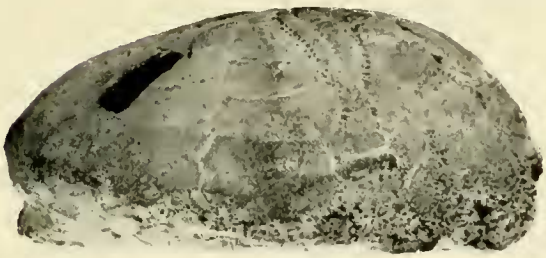

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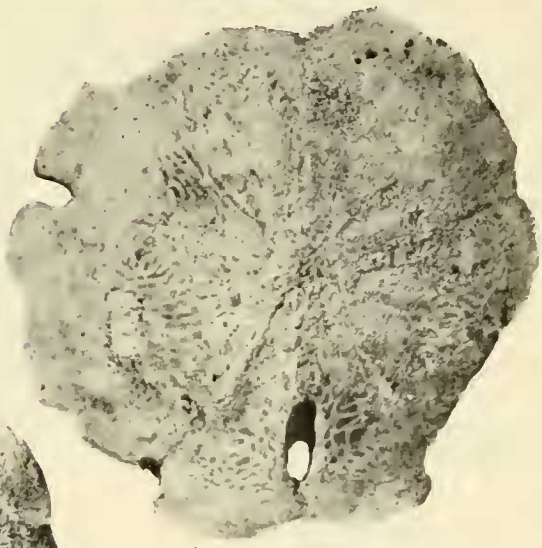

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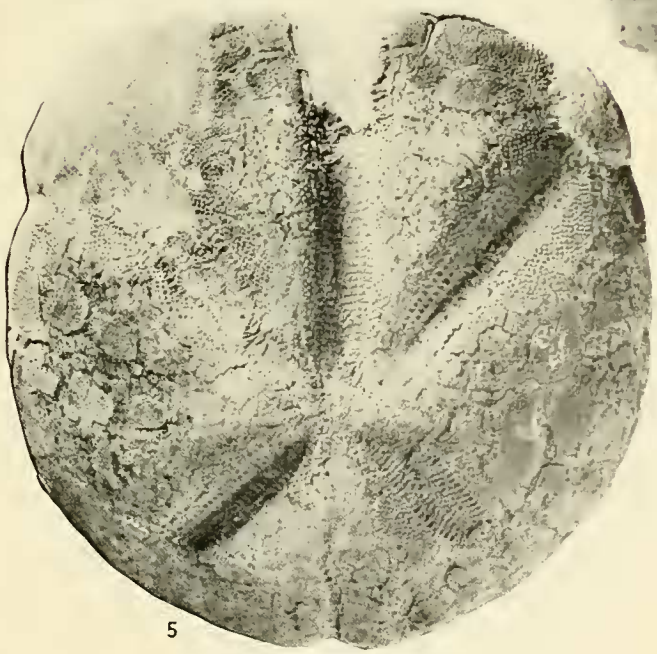

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EXPLANATION OF PLATE 26

FIG. 1. *Brisaster townsendi woynari* Hertlein and Grant, new subspecies. Holotype (Los Angeles County Museum), from Loc. 107 (LAM), clay quarry at end of Arroyo Drive, San Diego, California. Length 91.5 mm.; width 90 mm.; height 34.5 mm. Aboral surface. A portion of the right side of this specimen is covered with hard concretionary sandstone. P. 132

FIG. 2. *Brisaster townsendi woynari* Hertlein and Grant, new subspecies. Posterior end of specimen shown in fig. 1.

FIG. 3. *Brisaster townsendi woynari* Hertlein and Grant, new subspecies. Oral surface of specimen shown in figs. 1 and 2.

FIG. 4. *Echinometra* sp. Hypotype (California Academy of Sciences), from Loc. 1413 (CAS), Pacific Beach, San Diego, California. Maximum diameter 19.2 mm.; height 8.3 mm. Side view. P. 114

FIG. 5. *Echinometra* sp. Oral surface of the specimen shown in fig. 4.

FIG. 6. *Arbacia incisa* A. Agassiz. Hypotype (California Academy of Sciences), from Pacific Beach, San Diego, California. Diameter 7.6 mm.; height 3.8 mm. Side view. P. 108

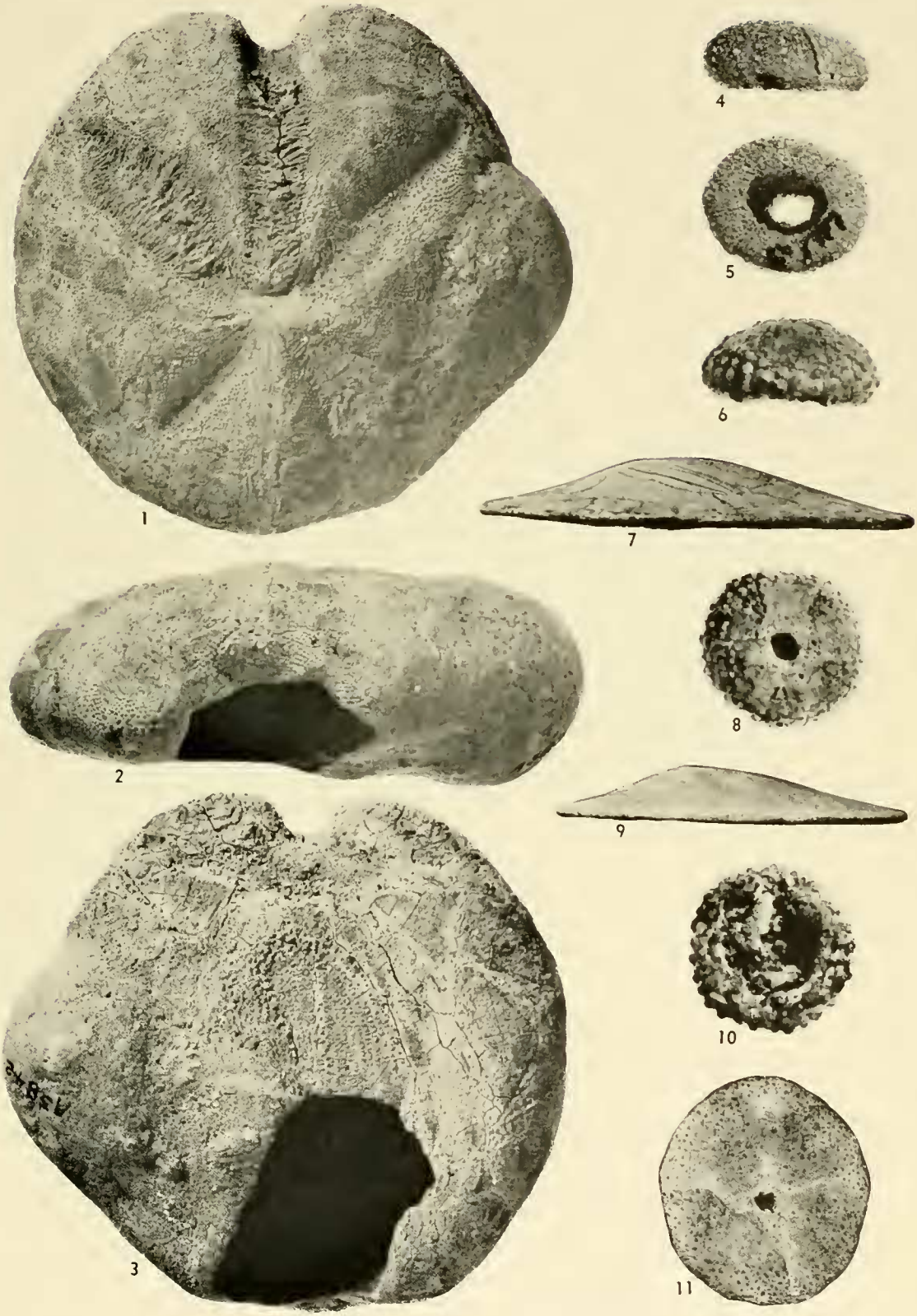
FIG. 7. *Dendraster ashleyi ynezensis* Kew. Hypotype (Los Angeles County Museum), side view of specimen shown on plate 21, fig. 5. Anterior end toward the right. P. 118

FIG. 8. *Arbacia incisa* A. Agassiz. Aboral surface of specimen shown in figs. 6 and 10.

FIG. 9. *Dendraster ashleyi* Arnold. Side view of specimen shown in plate 21, fig. 6.

FIG. 10. *Arbacia incisa* A. Agassiz. Oral surface of specimen shown in figs. 6 and 8.

FIG. 11. *Merriamaster pacificus* Kew. Hypotype (Los Angeles County Museum), from Loc. 122 (LAM), 20 to 30 feet below end of Loring Street, Pacific Beach, San Diego, California. Length 24.3 mm.; width 22.8 mm.; height 6.4 mm. Oral surface of a slightly crushed specimen. See also plate 25, fig. 6. P. 124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